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The Rearmament Programme

THE tenth report to be made this session by the House of Commons Select Committee on Estimates was published by H.M. Stationery Office at the end of last week. It deals with several matters related to the rearmament programme, saying that the committee considers that there is a need to review all major works now in progress or contemplated. Shortages of materials and labour, the report states, are complicating accurate estimates of costs, and the committee recommends that the Ministry of Supply should review all works, which are ancillary to any of its main projects, in order to ensure that the manner in which they are carried out conforms to the limitations of the present financial situation. In the report it is urged that there is need for a proper allocation of priorities between long-term and short-term projects. Reference is also made to the system of priorities, introduced in recent months, which takes into account the needs of industry and the export trade, the committee's impression being that the system is not yet working satisfactorily. It is suggested in the report that " urgent steps " should be taken by the departments concerned, in consultation with representatives of trade and industry, to review the present situation, and the hope is expressed that the Estimates Committee of the next session of Parliament will make a full inquiry into the whole system of priorities. The report goes on to state that the select committee has received further evidence on the problem of obtaining sufficient staff in all the establishments engaged in the rearmament programme. But although there is difficulty in obtaining skilled labour, the situation at present appears to be reasonably satisfactory apart from the call-up of apprentices and the supply of scientific staff in Government establishments. One recommendation made by the committee is that apprentices should never be called up until their apprenticeship has been completed. Another recommendation is that consideration should be given to the creation of some form of technical reserve, similar to the railway companies of the Royal Engineers, in which skilled men who have completed their apprenticeship should carry out their military service.

International Congress of Bridge and Structural Engineering

FOLLOWING the technical sessions which were held in Cambridge last week, the fourth congress of the International Association of Bridge and Structural Engineering has continued this week with various visits to places of engineering interest in the home counties, and with social functions. On Saturday, August 30th, the Minister of Transport, Mr. Lennox Boyd, received the congress delegates at a Government reception at the Tate Gallery, and on Monday, September 1st, a banquet was held at Guildhall, attended by some 700 delegates and guests. The toast of " The Lord Mayor " was proposed by Mr. F. S. Snow, and Alderman Sir F. M. Wells, Bart., responded. The toast of " The International Association of Bridge and Structural Engineering " was proposed by Mr. David Eccles, Minister of Works, with replies by Professor Stussi, president of the association, and by Mr. E. S. Andrews, president of the congress organising committee. During the course of his speech Mr. Eccles pointed out that the Ministry of Works had a general responsibility for the civil engineering industry and was itself a building department. He thought it was his duty to see that all Government building embodied the latest knowledge and practice in the art of construction, and he did not think a Government Department ought to undertake the business of production unless it was confident that by doing so it could give an example to the public at large. He was therefore impatient to learn about the results of the congress. The Ministry would try out on building sites all that promised to be of value in its constructional work, Mr. Eccles went on, and would see that the results of those trials were made known to the civil engineering industry. He was particularly interested in the problem of saving steel. Mr. Eccles continued by saying that he was well aware that new techniques in construction had an importance which went far beyond Great Britain. The whole world was crying out for capital works, he said, and we must prove to the populations with a low standard of life that we could help them to create the basic services of transport, power and irrigation.

The Late Sir Walrond Sinclair, K.B.E.

WE have learned with regret of the death of Sir Walrond Sinclair, which occurred in London, after some months of illness, on Saturday last, August 30th. Sir Walrond, who was seventy-two, had for many years occupied a prominent position in the tyre and rubber industry, and at the time of his death was the president of the British Tyre and Rubber Company, Ltd. Sir Walrond joined that company in 1924, when it was formed under the title of the British Goodrich Rubber Company, Ltd., and from 1925 to 1942 was its managing director. He was appointed chairman in 1927, in which office he continued until quite recently, when, on account of failing health, he felt compelled to resign. The board then elected him president of the company. In addition to his work for the British Tyre and Rubber group of companies, Sir Walrond held many important offices in the rubber industry. He had served successively as president of the Tyre Manufacturers Conference, the Institution of the Rubber Industry, and the Federation of British Rubber Manufacturers' Association. In the first world war Sir Walrond was attached to the War Office on the staff of the Adjutant-General, and in 1917 he was appointed Assistant Adjutant-General. Later in the same year Sir Walrond was transferred to the Ministry of National Service, becoming director of national service for the London and South-Eastern Region. He was created K.B.E. in 1918. When the second world war came Sir Walrond was called upon immediately by the rubber manufacturing industry to institute and direct the voluntary control scheme for rubber. He relinquished his office as controller in October, 1940, when he was invited to accompany the British Mission to South America organised by the Department of Overseas Trade.

Taxation and the Shipping Industry

THE " excessive taxation burden " which has to be borne by the British shipping industry is commented upon by Sir Ernest Murrant, chairman of Furness, Withy and Co., Ltd., in a statement circulated with that company's annual report. For many years, the statement says, the shipping industry has laboured under an excessive tax burden, and on every appropriate occasion strong representations have been made urging the necessity for changes in the method of assessment. Sir Ernest emphasises the very special problems of the shipping industry. Not merely, he observes, is the industry essentially international in character, and not merely is its problem of replacing obsolete tonnage materially different from the replacement problem of every other industry. It is generally admitted that shipping is a key industry in relation to national defence and is also one of the chief contributors to those all-important exports, invisible though they may be. Shipbuilders, Sir Ernest adds, call for a continuous stream of orders for new ships and Governments of all colours and creeds call for the maintenance of an adequate and efficient merchant marine. Because, Sir Ernest comments, the industry has so far been successful in the enormous efforts that have been made in rebuilding the mercantile fleet to pre-war proportions, it seems to be inferred that all is well ; that the camel may groan, but its back won't break !

Potato Harvesting Machinery Competition

THE Royal Agricultural Society has announced that Mr. T. J. Caudwell, of Spalding, Mr. J. E. Rennie, of Macmerry, East Lothian, and Mr. R. W. Ward, of Newport, Shropshire, have consented to serve as judges for the forthcoming potato harvesting machinery trials. The trials are to take place in the Eastern Counties and the West Midlands, and a public demonstration of all the twenty-five machines entered for the competition will be held on the farm of the Harper Adams Agricultural College, Newport, Shropshire, on October 9th and 10th. The machines entered include all the British potato harvesters commonly regarded as now in production, as well as several prototypes. In addition, there are three entries from Sweden, one from Denmark, and one from Holland. The object of the competition is to stimulate the production of machinery for the more complete and effective harvesting of potatoes. The machines entered for the trials were subject to inspection before acceptance and, whether as a single machine or group of machines, had to be capable of undertaking the full sequence of operations from lifting the potatoes from the ridge to depositing them direct into bags or a bulk container or vehicle travelling with the machine. These competitive trials are the second to be carried out by the Royal Agricultural Society since the war. The earlier series of trials, which were concerned with forage harvesting and handling machinery, were made two years ago.

Water Supply in Glasgow

THE annual report of the Glasgow Corporation Water Department for the year ended May 31st, 1952, has recently been published. In spite of contemporary difficulties, which are common to many similar undertakings, the department continued to make substantial progress in water supply during the year under review, and no less than 26,119 new water supplies for new housing were supplied, whilst the supply to the whole area of over 90 square miles was improved and strengthened ; the daily consumption of water to the city increased from 84·7 to 86·4 million gallons. Of the major engineering works which the department now envisages, mention should be made of the Clyde water tunnel, to take the department's new west main, the water for which has now been approved by the Corporation, and which will involve work of major importance in compressed air under the River Clyde, and the decision to obtain an additional source of supply from Glenfinlas, where an intake is to be constructed, to supplement the supply which has been obtained from Loch Katrine and Loch Arklet for almost a century. The report points out that wages have increased by about 15 per cent in the period February, 1951, to February, 1952, and the price of 36in diameter cast iron pipes has risen by 21½ per cent over the same period ; no less than 10 miles of such pipes are required for the west main alone. Many other materials have become more costly, but, the report points out, it is heartening to note that such basic materials as lead and cement have in recent weeks shown slight reductions in cost.

Approach to Labour Turnover

By J. M. M. HILL

A high rate of labour turnover is costly to the employer because of the expense of training new labour. This article suggests and discusses a new approach to the problem, whereby labour turnover is studied as part of a continuous social process instead of concentrating on a single incident—an employee's decision to leave. The author illustrates this approach by quoting from work carried out by the Tavistock Institute of Human Relations, with the help of the Glacier Metal Company. In this work it was decided to follow the experiences of a group of employees from the time of their engagement until leaving the firm.

THERE are several factors intertwined in the general problem of labour turnover, and in this article I shall try to sort a few of them out and to propose an approach to the problem rather than attempt to provide solutions. This approach differs from those in current use and throws some light on the reasons why so many current solutions have proved disappointing. Works managers and others have long been concerned that under conditions of full employment labour is hard to get and it is the experience of many firms that having got it, it is hard to keep. New labour is often costly to train and the financial loss involved in high labour turnover is considerable. The cost per separation to the firm concerned may be as high as £100. Hence the orthodox approach to labour turnover has tended to concentrate attention on leavers and the orthodox measure of labour turnover is to express the number of leavers in a period as a percentage of the average number employed during that period. A typical picture of the monthly labour turnover from a London factory calculated in this way is shown in Fig. 1.

The oscillations revealed, apart from the high peaks in 1945 and 1949, may be demonstrated to be random, and are, indeed, to be expected in a situation where the shortness of the work contract allows leaving decisions to be implemented without delay. In what follows we shall be more concerned with the general level of the rate of leaving about which these fluctuations occur. In order to investigate this adequately, a preliminary shift of emphasis must be made and one can suggest immediately that the mere fact of someone having left an organisation is in itself of less importance than the length of time they have been there. As Keynes pointed out in a different context, " In the long run we are all dead," and similarly in the long run anyone belonging to an organisation must leave it. The important thing for the firm concerned is how much they have been able to serve it before they leave.

It is the experience of social scientists that many social and economic problems are tackled on the basis of the emotional reactions to them (which may be unconscious), rather than on the basis of the consciously expressed problem. The consciously expressed problem in the case of labour turnover lies in its cost and wastefulness, but there are emotional factors underlying this which we may now briefly examine. First of all, the leaving of an employee from any organisation, if freely undertaken, may be regarded as a double rejection. It is a rejection of the individual by the organisation in question, and from the point of view of the organisation, perhaps more importantly, a rejection of it by the individual. If someone comes to work for you, you can regard it, in some sense, as a compliment, if they leave you, you may well regard it as an insult. It is common experience in daily life that one is worried less by the compliments one receives than by the reverse. Hence one reason for the concentration of the problem upon the leaver rather than on the stayer.

In tackling the problem in industry, this concentration on the leaver has led to an elaborate procedure of exit interviewing of employees who leave the organisation. By this means it is hoped to discover the "causes" of labour turnover. But an analysis of reasons for leaving may well yield, from the practical point of view, extremely disappointing results. Consider, for example, the grossest category used, that is a classification of reasons for leaving in terms of employee or employer request, i.e. resigning or being dismissed. It is very rarely necessary for any individual to be dismissed, most of the reasons given for dismissal are the sort of things for which the employee is warned several times, and the persistence in a misdemeanour, such as being late, or being insolent to the foreman, comes after all from the employee himself, and hence to be dismissed for this sort of thing might just as well be termed " employee request." If, then, we cannot trust such a gross distinction as this, how can we place much reliance on more detailed reasons for leaving? There is also a surprisingly common story, about the employee who leaves to "emigrate to Australia," and who turns up a few weeks later at the factory down the road.

I shall suggest in the course of this article that labour turnover may be more usefully regarded as a process which does not wholly lie within the individual and hence cannot easily be explained by him, i.e. that it is a social rather than an individual phenomenon. Once we can dissociate ourselves from these emotional feelings of rejection which are occasioned in a factory by the desire of its employees to leave it, we can see that leaving can be regarded as only one instance in a whole life which starts with engagement, and it is to this " whole life " that we shall turn our attention.

The Representation of Labour Turnover as a Social Process

In work with the Glacier Metal Company, carried out by the Tavistock Institute of Human Relations*, it was decided to examine labour turnover from this point of view, and to follow through a group of employees from the time of their engagement or " starting " until their leaving. In order to clarify this aspect of labour turnover, we shall consider what is involved in some detail. In accordance with this approach, each employee can be regarded as both a starter and a leaver. These two terms should not be regarded as applying merely to specific events, nor to roles carried by each employee at two sharply defined periods of time, but to roles carried by each employee during his entire service. When he starts he has already begun to leave and in a sense until he leaves he is still a starter. Just as, in one sense, a man can be said to begin to die as soon as he is born, the processes of decay and replacement occurring simultaneously, but with a steady change in their relative strengths so " starter " and " leaver " can be considered as roles which every employee carries continuously throughout the period of his employment. In the individual employee the relative strength of the two roles, that of starter and that of leaver, is undergoing constant change as he moves through his term of employment until the process is completed with his final departure. The composition of a group of entrants is also undergoing constant change as different individuals leave at different times.

All entrants to the Glacier Metal Company for the year 1942, 750 in all, were followed up and from the dates of their engagement and separation their length of service was calculated. When lengths of service were grouped into twentysix week periods, and the percentage of the original entrant group leaving during each period was calculated, the results shown in Table I were obtained.

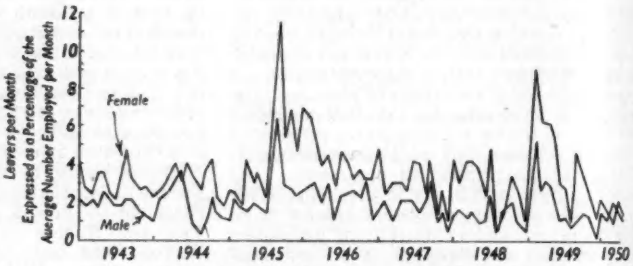

Fig. 1—Monthly Labour Turnover in a London Factory

TABLE I—*The Glacier Metal Company: Lengths of Service of* 1942 *Entrants*

Lengths of service (weeks)	Number of employees	Percentage of total entrants
0–25	203	27
26–51	98	13
52–77	78	10
78–103	58	8
104–129	45	6
130–155	31	4
156–181	55	7
182–207	38	5
208–233	24	3
234–259	11	1
260–285	7	1
286–311	6	1
312–337	7	1
338–363	8	1
Over 363	81	12

Total number of entrants = 750

It can be seen that the frequency distribution of these lengths of service forms a fairly definite pattern ; the decay in numbers of the original entrant group proceeding regularly except for one disturbance conforming roughly to the period at the end of the war. Examination of succeeding entrant groups showed that the patterned regularity observed in the behaviour of the 1942 entrants was reproduced for these other groups. That is to say that the process uncovered was not only fairly regular in shape, but

* This work is described in *The Changing Culture of a Factory*, by Elliott Jaques, Tavistock Publications, 1951. Three studies of Labour Turnover in the Company have so far appeared, viz., " The Representation of Labour Turnover as a Social Process," by A. K. Rice, J. M. M. Hill and E. L. Trist, *Human Relations*, 1950, Vol. III, No. 4, " A Consideration of Labour Turnover as the Resultant of a Quasi-Stationary Process," by J. M. M. Hill, *Human Relations*, 1951, Vol. IV, No. 3, and " An Examination of the Boundaries of Part-Institutions," by A. K. Rice, *Human Relations*, 1951, Vol. IV, No. 4. This latter is a study of inter-departmental labour turnover.

showed some degree of constancy over time as well. In Table II is given the frequency

TABLE II—*The Glacier Metal Company: Lengths of Service of Employees Entering from* 1942 *to* 1945

Lengths of service (weeks)	Number of employees	Percentage of total entrants
0–25	491	30·61
26–51	257	16·02
52–77	173	10·78
78–103	110	6·86
104–129	87	5·42
130–155	60	3·74
156–181	82	5·11
182–207	56	3·49
Over 207	288	17·97

Total number of entrants = 1604

distribution of lengths of service of all entrants to the Glacier Metal Company from 1942 to 1945, the larger entrant group taken exhibiting, as might be expected, a smoother rate of decay. These results are illustrated in Fig. 2.

The relative constancy over time of the labour turnover process in the company assumes some significance when one considers what had taken place during the period studied—the years 1942–50. A number of major changes had occurred in the factory—for example, a substantial growth in joint consultation, alterations in the wages structure, reorganisation of departments, technological changes and so on. Even more dramatic events occurred in the external community which had a direct bearing on the factory and, one would think, on whether or not individuals would leave or remain in their employment—for example, the call up of men and women for the Services, restrictions on labour mobility, demobilisation and the reinstatement of ex-Service personnel, reconversion of industry to peacetime production, the expansion and contraction of markets and the effects of the devaluation of sterling.

We must, however, note here a distinction with regard to our data which, unless made clearly, can cause confusion. By the regularity of the distribution we refer to its conformance to a mathematical pattern. By the constancy of the distribution we mean the recurrence of this mathematical pattern for succeeding groups of entrants. The shape of the distribution in this case is that of a hyperbolic function which is shown fitted to the data presented. This has a general formula, $y=ax^b$, where a=the percentage of the original entrant group leaving in the first period, and b measures the (negative) slope of the curve. Although we would normally expect some form of decay function, or highly skewed curve to fit data of this sort, the actual curve giving the best fit to any particular set of results is irrelevant to our main thesis. What is important is that leaving can be expressed for the Glacier Metal Company at least as a function of length of service, leaving only a comparatively small residual variance unexplained, or ascribable to other factors. However, in this case and in all others so far examined, a hyperbolic function is found to give an adequate fit and we may consider, consistently with other experience, that the process revealed by this sort of shape has three broadly distinct phases through which any entrant group passes. These phases may be described as follows:

First, the period of "induction crisis," during which a peak occurs in the distribution with a relatively high proportion of entrants becoming casualties as a result of the initial interaction between the engaging company and the entrant group.

Secondly, the period of "differential transit," during which those who survive the induction crisis learn the ways of the company and discover how far they have a place in it.

Lastly, the period of "settled connection," when those who have survived the first two periods take on the character of "quasi-permanent" employees. In this period leaving is intermittent and shows little tendency either to increase or decrease, i.e. the curve has flattened out.

Customary ways of looking at labour turnover—perhaps to some extent for the reasons I have suggested—have focused attention

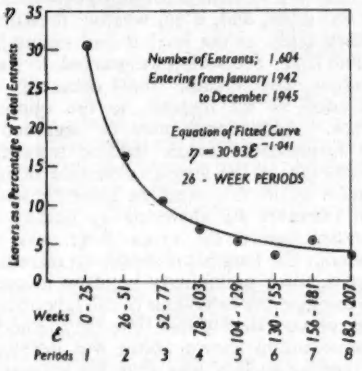

Fig. 2—Leavers as a Percentage of Entrants, 1942 - 1945

on the individuals falling in the first phase—sometimes called the marginal group, the "drifters," "floaters," and so on, and less frequently on those falling in the third phase—the "hard core," or stable labour force. Little attention has, however, been paid to those falling in the middle phase—the period of differential transit. Hence, the conventional dichotomy has tended to obscure the fact that these groups represent the two end points of a continuing process.

The discovery that leaving may be regarded as a function of length of service has been checked in another factory differing from Glacier in its product, structure, position, type of labour and personnel practices. The Glacier findings are confirmed—although, as might be expected, the curve for this factory has a different value. The records in this case were only available for entrants from 1944–1947 inclusive, and the steepness of the curve makes it convenient to distribute the values in thirteen-week periods. The results, in comparison with those of Glacier for the same period, are shown in Table III and Fig. 3. Both these firms operate the same kind of work contract and have a pre-

TABLE III—*The Glacier Metal Company and the "X" Factory: Lengths of Service of Employees Entering from* 1944 *to* 1947

Lengths of service (weeks)	Number of employees		Percentage of total entrants	
	Glacier	"X"	Glacier	"X"
0–12	242	523	20·07	67·66
13–25	152	88	12·60	11·38
26–38	104	46	8·62	5·95
39–51	73	13	6·05	1·68
52–64	52	12	4·31	1·55
65–77	47	10	3·90	1·29
78–90	49	6	4·06	0·78
Over 90	481	75	40·39	9·71

Total number of entrants: The Glacier Metal Company = 1206
The "X" Factory = 773

dominantly employee-request type of labour turnover, probably the result of the full employment situation which has obtained during these years. It is suggested that, given these conditions at least, the differences between the data may be related to gross differences between the social structure and culture of the two factories.

Thus, the evidence so far is that a phenomenon observed in two separate factories has made possible the formulation of a hypothesis concerning the nature of labour turnover which makes sense of facts difficult to account for in any other way and has even at this stage considerable theoretical consistency.

A Theoretical Framework

It is, however, interesting to note that this general hypothesis is consistent with a theoretical analysis of a community in field theory terms by using some of the concepts developed by the late Kurt Lewin†. The argument may be presented as follows.

The field which we are considering is that of employing institutions—that is to say, any institution which engages people to work for it. This may include factories, schools, universities, shops, prisons, the Army or any of the multiple organisations which make up our economic society. First, employing organisations are characterised by the type of work contract they operate within the scope of which individuals enter or leave. In the majority of our institutions entering and leaving are free—that is to say, an individual works on the basis of, perhaps, a weekly or monthly contract and may terminate his contract at short notice. Hence the pattern of behaviour of individuals passing through such an institution is freely affected by the social forces involved. This is, of course, not so in the case of a prison or an army where the contract may be for anything up to twenty years and be enforce-

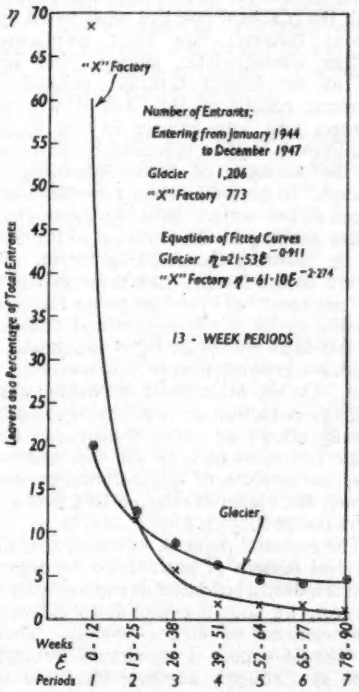

Fig. 3—Comparison of Labour Turnover Distribution in Two Factories

able by strict legal sanctions. Any institution is at any time composed of people who have joined it, and who must, eventually, leave it, for the making of an engagement implies the breaking of it at some time or other in the last analysis, at physical death. Thus,

† Kurt Lewin, 1890–1947. Professor of Psychology and Director of the Research Centre for Group Dynamics, Massachusetts Institute of Technology. More than anyone else, Lewin has demonstrated the possibility and practice of studying Social Dynamics with a scientific precision usually regarded as the prerogative of the "established" sciences.

for our purpose, an employing institution may be simply defined by the people in it at any one time but, for it to persist through time, leavers must be replaced and, if the institution is to remain unchanged in its unique institutional characteristics, some form of social process is implied which will maintain these characteristics. Such a process may be of the kind which Lewin has called a quasi-stationary process: that is a process which maintains its apparent constancy through the interaction of a series of opposing forces of equal strength. In terms of Lewin's formulation also, and this is important, this maintenance of stability will involve a self-regulating mechanism. Biological analogies abound and, for example, the sustainment of bodily temperature or weight may be regarded as the resultant of quasi-stationary processes involving a self-regulating mechanism.

The level at which such a process operates in any particular case is determined by the strength of opposing forces in quasi-stationary equilibrium. In terms of life within an institution, that is to say, the length of time which an employee remains with a firm, which is here our consideration, these forces may be regarded as the ones that tend towards either lengthening or shortening the period of service of individuals. The question, "Why do you want to leave?" is thus no more relevant than the question, "Why do you want to stay?", and in neither case is it likely that the individual to whom the question is addressed will be able to give a complete answer.

These social processes are, of course, seldom perfectly constant, but they show fluctuations about an average level of equilibrium. As we are concerned ultimately with the practical point of what to do about labour turnover, we must emphasise a further characteristic, namely, that in so far as the labour turnover process is a dynamic reality of this sort it will resist change, and any change in the level of equilibrium may be preceded by an increase in the strength of forces opposing that change. In general, a change can be brought about in two ways; either by increasing the forces pushing in the direction of the change or by reducing the resisting forces. With regard to the former, Lewin points out that the net result will tend to be an increase of tension in the whole system and techniques of this kind will often have undesirable by-products in symptoms of this increased tension. On the other hand, producing change through reduction or removal of resistances usually allows an easier transition. For a fuller treatment of both the theoretical and practical aspects of quasi-stationary equilibrium, the reader is referred to Lewin's own work on the subject. ‡

The essential point is, however, that if the survival pattern of entrants to an organisation is indeed a reflection of a quasi-stationary process, we should expect it to exhibit the characteristics of such a process. That is, we should expect it to remain throughout time at a roughly constant level and tend, if forced temporarily to change, to return to this level by a self-regulating mechanism. We should expect also that any such forced change might be preceded by an increase in the opposing forces, resisting the change. All this is, of course, dependent on the basic institutional characteristics remaining unchanged. If these do change, or if the forces exerted in the surrounding community are of such a gross character as to blot out the institutional forces entirely, we should expect a corresponding effect upon the process.

‡ See especially two articles under the title "Frontiers in Group Dynamics," *Human Relations*, Vol. I, Nos. 1 and 2, 1947.

The Labour Turnover Process in a Redundancy Situation

An opportunity to examine some of the questions thrown up by these considerations was offered by an incident which occurred in the Glacier project over the years 1948–1950. During this time the institution persisted basically unchanged, but at the beginning of 1949 there was a redundancy crisis which was explicitly perceived as resulting from the external market situation. The crisis lasted for about four months and large numbers of employees were declared redundant. First, then, we wanted to know whether the survival distribution was affected by this crisis, and, if so, whether it returned subsequently to the level it had maintained previously. Secondly, we wanted to know whether any change that occurred was preceded by an increase in the opposing forces. Redundancy may be regarded as the resultant of forces tending towards a shortening of the length of service of individuals in the firm, and the second question can therefore be answered by finding out whether before the crisis there was any tendency for lengths of service to increase—that is, for a preliminary build-up to occur. To examine the behaviour of the labour turnover process during this time the method of representation shown above was developed further in such a way that for succeeding small groups of entrants changes in the survival distribution could be detected while they occurred. The method involved predicting entirely from data about entrants the numbers of employees who would leave the factory in monthly periods, on the assumption that the basic pattern persisted unchanged, and then comparing this with the actual numbers who did, in fact, leave. Owing to incomplete records the inquiry had to be concentrated on those employees who entered in 1942 and subsequently. The results are shown in Table IV. Referring to the yearly figures we find that in 1948, had the process been operating consistently, we would have expected 306 to have left. The actual number of leavers was 225, so that eighty-one employees were still with the firm whom we would have expected to have left. In 1949—the year of the redundancy crisis—the relevant figures are 197 expected and 273 actual, i.e. seventy-six more employees left than we would have expected, which more or less cancels out the surplus from 1948. Over the three years 1948–1950 the number of expected leavers was 781 and the number of actual leavers 780. Hence, preceding the redundancy crisis, there was a tendency for employees to stick with the firm longer than they had been doing, and the extent of the crisis was just such as to remove the surplus thus built up. Reference to the monthly data shows that this tendency was apparent right from the early months of 1948—almost a year before the actual redundancy crisis and about six months before the market situation began to cause anxiety. Such was the resistance to change of the labour turnover process in this case.

Table IV—*The Glacier Metal Company: Actual Leavers Compared with Expected Leavers, Calculated on the Assumption that the Labour Turnover Process Operated Consistently*

Date	Leavers generated by post—1942 entrants		Differences: actual minus expected	
	Expected	Actual	Simple	Cumulative
1948				
January	26	18	− 8	− 8
February	27	23	− 4	−12
March	26	20	− 6	−18
April	28	21	− 7	−25
May	28	19	− 9	−34
June	27	16	−11	−45
July	26	36	+10	−35
August	25	9	−16	−51
September	24	21	− 3	−54
October	23	25	+ 2	−52
November	23	12	−11	−63
December	23	5	−18	−81
Totals 1948	306	225	−81	—
1949				
January	21	43	+22	−59
February	20	62	+42	−17
March	18	23	+ 5	−12
April	17	43	+26	+14
May	17	24	+ 7	+21
June	16	10	− 6	+15
July	15	9	− 6	+ 9
August	14	11	− 3	+ 6
September	14	18	+ 4	+10
October	14	14	0	+10
November	14	10	− 4	+ 6
December	17	6	−11	− 5
Totals 1949	197	273	+76	—
1950				
January	18	20	+ 2	− 3
February	20	15	− 5	− 8
March	21	24	+ 3	− 5
April	22	20	− 2	− 7
May	23	16	− 7	−14
June	24	25	+ 1	−13
July	24	21	− 3	−16
August	24	18	− 6	−22
September	23	47	+24	+ 2
October	25	21	− 4	− 2
November	27	26	− 1	− 3
December	27	29	+ 2	− 1
Totals 1950	278	282	+ 4	—
Grand totals	781	780	− 1	—

Summary and Implications

Before going on to indicate further lines of inquiry and the sort of work now being undertaken in an attempt to elucidate the process still further, we may briefly summarise the position so far.

We have shown that labour turnover is a real objective problem, but that current methods of tackling it may become overlaid by emotional attitudes and, hence, tend to concentrate on leaving. The consideration that leaving is after all only one episode in the life of an employee, a life that begins with his engagement by the firm has led us to develop a method of measuring the whole life of all employees. We have thus obtained a measure of a kind of social metabolic rate. We have then considered a theoretical analysis of a community, in terms of the life of its employees, and from this theoretical analysis have found out that we should, in fact, expect that a social process would be involved and have also deduced some of the characteristics of this social process. We have shown that there are reasons to believe that the survival distribution which we have obtained, represents a reflection of the social process which we have deduced must exist in order for any institution to continue to live as an institution. This has led us, first, to an explanation of the disappointing results which previous labour turnover research has yielded, and it has, at the same time, shown us the complex nature of the work that must be done in order that the labour turnover problem may be further tackled.

In which direction, then, does the next stage lie? Obviously, if we postulate and accept the existence of a labour turnover process of the kind I have described we should now go on to attempt to define more precisely the determinants of its level. In slightly different terms we could ask—"Why does one group of people attract new members and retain them with little loss of numbers and that over a relatively long period, while another group, even if it attracts new members, cannot retain the majority of them for more than a very short time?" The survival distribution of entrants yields us an instrument with which we can measure this rate of social absorption in precise terms. Its general nature is illuminated by Lewinian concepts and confirmed by experience. We have now to investigate more closely still what it is that we are measuring, and, more importantly, the conditions which will allow change to take place.

Current research is being directed not towards validating the Glacier result for

several other factories *in toto*, but towards considering the relation which the whole social process of the factory bears to such social processes as exist in its component parts. It has been found possible to regard a sub-institution of a factory, for example, a particular machine shop or the Finance Department or any other section, as a complete sub-institution in itself. The survival distribution of entrants into these component parts can be measured and the first result that comes out of this is that the characteristic behaviour of individuals passing through a shop is similar whether these employees enter the shop in question from outside the factory or from another department. That is to say that the transfer of an employee from one department to another has the effect of beginning for him a new "life" within the factory. This seems to confirm the independent expectation that an individual experiences an organisation of which he is a part through his immediate surroundings, i.e. his own working group, rather than through his relationship with the whole organisation.

Now it is common practice in industry to give a new employee an induction course into the factory as a whole. This normally consists of a tour of the works together with talks, and often a little booklet about its history and its relation to the wider economic environment is supplied. The essential point is that all too often he is told what interests management and what they want him to know, rather than what he wants to know himself. But he will experience his job not through the factory as a whole, but through the personalities of that little section of which he is to become a part, and it is not so common practice to regard it as necessary to give a newcomer to any particular department an induction course into that department, still less into the smaller working groups which compose it. We may suggest, however, that it is more important to induce a newcomer to the small group he will experience than to the whole organisation.

Alongside this, we may ask ourselves the question, "What function does a social organisation perform in respect of the members of it ?" A man comes to work ostensibly to get money with which to purchase the necessities of life, and, if questioned, he might vehemently assert that he goes to work for no other reason, but nevertheless, once at work he becomes subject to all the social pressures of the organisation which he has entered, and he experiences them as pleasant or unpleasant, satisfying or unsatisfying as an outlet for his aggression, for his desire for approbation, and so forth. The so-called marginal floaters, i.e. the men who drift from job to job are often those who can, in fact, only gain satisfaction by being sacked, and the function which an organisations performs for these men may well be to allow them a release of tension resulting from a social or personal maladjustment which has never been adequately resolved inside them. It may, of course, be difficult for a personnel manager to realise this, for to do so involves the realisation that of the many men who pass through his hands week by week, and for whom he tries to do his best, a large proportion may desire nothing more of him than that they may be forcibly ejected from the organisation which they, nevertheless, have chosen to serve. This is not really so startling an idea as it appears on the surface, for reflection, I think, will show in the case of most of us that we have at one time or another gained pleasure not only in belonging to an organisation, but in not belonging, and so demonstrating our independence of certain societies whose demands on us we resented. From this point of view, it seems that for many factories a reduction in labour turnover may not necessarily be a good thing in itself, and a healthy organisation may well be that which can easily eliminate those who have finished with it. The attempt to retain some employees for too long may result in an increase of total tension.

These are only a few of the lines of inquiry opened up by this new approach to labour turnover. The extent of our knowledge of the subject makes it impossible to advance ready-made solutions for the problems encountered. Labour turnover is concerned with human relations, and like other problems in this field cannot be solved with the same brisk efficiency with which machinery can be oiled. Nevertheless, in the social sciences as in the physical, the only real progress is made along the lines of patient scientific inquiry.

Small Self-Acting Gas Pressure Regulators

By H. R. RONNEBECK, M.Sc.*

In research at high-pressures the need frequently arises for a pressure regulator to handle small gas rates (up to 10 cubic metres per hour at N.T.P.) at pressures up to 300 atmospheres or more. The required exit (downstream) gas pressures may also be higher than can be provided by commercially available pressure regulators. Three types of regulator are here described and illustrated.

Introduction

THE following three kinds of small self-acting gas-pressure regulators have been developed :—

(1) A downstream pressure regulator for inlet pressures up to 350 atmospheres. This controls the exit pressure at any desired value between 20 and 100 atmospheres by means of a diaphragm subjected to an adjustable spring pressure on one side and to the downstream gas pressure on the other side. The inlet valve is operated by deflection of the diaphragm.

(2) A similar device in which gas pressure in a closed vessel is used instead of a spring, thus enabling the exit pressure to be controlled at any value between 20 and 300 atmospheres. This model is not normally used to maintain a pressure less than 100 atmospheres because the spring-loaded type is cheaper.

(3) An upstream pressure regulator acting as an accurate relief valve for pressures up to 30 atmospheres. The spring-loaded diaphragm is balanced by the upstream pressure so that the valve opens when the upstream pressure exceeds the pressure for which the spring is adjusted.

The three designs have the following four important factors in common :—

(*a*) They have "Fluon" valve seats which when closed can shut off practically gas-tight even with hydrogen at 350 atmospheres ; this seat design enables them to maintain their setting for very long periods.

(*b*) The change in gas pressure with change of rate of flow is exceptionally small ; thus, for the downstream regulators it is only 0·5 atmospheres over the whole range.

(*c*) As all parts exposed to the gas are of 18/8/Ti, Monel metal, or "Fluon," the valves can be used for a very wide range of gases.

(*d*) They can be arranged for remote pneumatic adjustment.

Pressure regulators of all three types have been in use on semi-technical and pilot plants, for more than eighteen months in some cases.

Self-acting gas-pressure regulators for oxygen cylinders are, of course, well known, but they are generally suitable only for maximum inlet pressures of about 150 atmospheres and maximum outlet pressures of about 200 lb per square inch. Types suitable for inlet pressures up to 350 atmospheres were required to give a steady downstream pressure of about 70 atmospheres : a new design was accordingly produced to work on the same principle as the oxygen reducing valve, but to suit much higher pressures. The satisfactory performance of this regulator led to the development of another model suitable for higher downstream pressures up to 300 atmospheres. This was required for maintaining a supply of hydrogen at a steady pressure of 250 atmospheres. As no spring of reasonable size could carry the load at this pressure and no thin diaphragm could stand such a concentrated load on one side to balance a uniformly distributed load on the other, gas pressure was used instead of a spring. A third type, the upstream pressure regulator, was next developed, in the first instance for limiting the output pressures of small two-stage gas compressors.

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Development of the Internal Valve

Choice of Materials.—The first downstream pressure regulator was made to incorporate a standard diesel engine fuel nozzle of the pintle type. These nozzles are precisely made with hardened and lapped pintle valves and valve seats. One of them worked fairly well in the regulator but was not quite gas-tight. Under their normal working conditions such valves would be lubricated by the fuel oil, but with gas they are liable to rust and stick. The valve and seat were therefore redesigned and made of 18/8/Ti with an "Alkathene" insert valve face. This was absolutely gas-tight and worked extremely well for inlet pressures up to about 100 atmospheres. Above 100 atmospheres the "Alkathene" tended to flow ; it was therefore replaced by "Fluon." At 300 atmospheres the "Fluon" began to flow but the trouble was eliminated by suitable heat treatment to harden it.

Heat Treatment of "Fluon" for Valve Faces.—With "Fluon" it usually pays to have even small parts specially moulded rather than machined. However, the $\frac{1}{8}$in discs used in these valves were rather too small and simple for this. In order to obtain a dense hard surface, the valve faces were cut from sheet "Fluon" which had been treated by quenching from 300 deg. Cent in water or between cold steel plates. The hard skin so obtained is from $\frac{1}{32}$in to $\frac{1}{16}$in thick.

Downstream Pressure Regulators for 350/20–100 Atmospheres

Arrangement.—Fig. 1 shows the forged steel body *A* and cover *B* ; between these is

clamped a 3 per cent chrome steel diaphragm *C*, 2¾in diameter by $\frac{1}{16}$in thick, the joint *D* being made with compressed, rubber-bonded asbestos fibre packing 0·008in thick. The diaphragm is heat-treated by heating to 870 deg. Cent., quenching in oil, reheating to 350 deg. Cent., and quenching in oil again. After this is ground on both sides to $\frac{1}{16}$in ±0·001in thickness. It must be made from sheet, not bar, because the latter may contain defects extending right through the disc.

The exit gas pressure under the diaphragm thrusts upwards against the springs *E*, *F*, which can be adjusted to balance any gas pressure up to 100 atmospheres. Any downward deflection opens the valve *G* to pass more gas so that the pressure is maintained to balance the spring load—see Fig. 2.

The valve seat *H* of 18/8/Ti forms gas-tight joints with the inlet stem *J* and with the body when the nut *K* is tightened. Fig. 2 shows the seat enlarged to twice full size. Its lower end ($\frac{1}{16}$in bore, $\frac{7}{32}$in o.d.) is flat and forms the valve seat, while its top surface is grooved to allow the gas to pass when the diaphragm is right down. The valve is

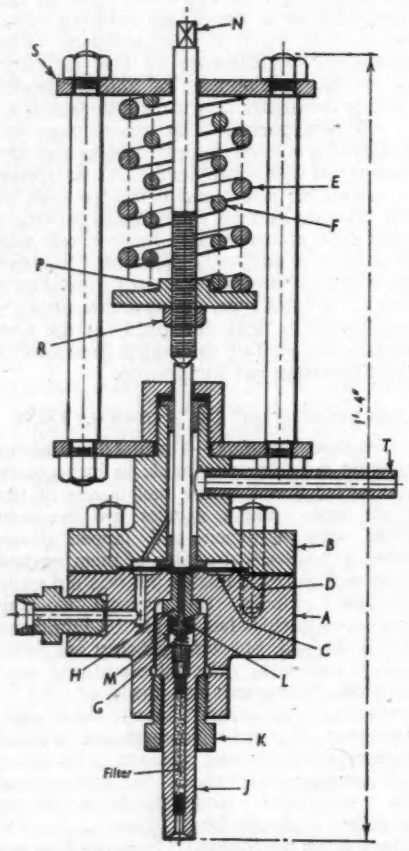


Fig. 1—Downstream Pressure Regulator, 350/20 - Atmospheres

made up of three parts, stem *G* of 18/8/Ti, valve face *L* of "Fluon" and sleeve *M* of Monel metal. After threading the face on the stem the sleeve is pushed over it and secured by crimping its thin skirt over the valve head with dies in a press.† A photograph of the regulator is reproduced as Fig. 8.

Pressure Adjustment.—The downstream pressure is adjusted by rotating the screwed spindle *N* so as to increase or decrease the spring pressure. Because of the friction between the springs and the compression plate *P* the latter will not rotate while the adjustment is being made. The nut *R* must, however, be locked to prevent a very slow creeping rotation which is liable to occur while the regulator is in use.

Remote Adjustment.—Provision is made for mounting a large diaphragm and cover on top of the spring plate *S*. The gas pressure can then be controlled from a distance by applying compressed air to the diaphragm.

Installation Precautions

Venting.—The vent pipe *T* (Fig. 1) is provided as a precaution against the escape of noxious gas in the event of a fracture

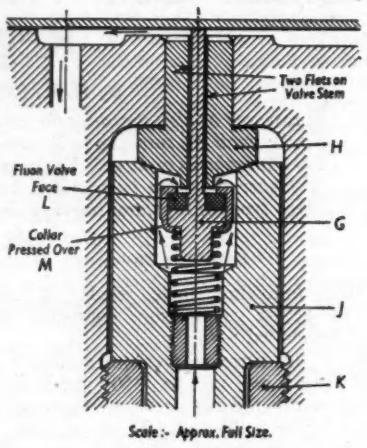


Fig. 2—Valve Assembly for Downstream Pressure Regulators

of the diaphragm. It can be connected to a pipe leading outside the building.

Filter.—Experience soon showed that a very good filter on the inlet side is absolutely essential. A "Purolator" filter element type M.F.26 in a suitable high-pressure vessel is recommended. The filter in the inlet stem of the regulator is intended only to stop particles which may have been left in the pipe between it and the filter during assembly. It was found advisable to make the connection between the filter and the regulator as short as possible in order to ensure that it should be clean. If the regulator cannot be mounted directly on the filter the pipe must be sand-blasted, washed out and dried before being installed. Grease must not be used to stick the lens ring in position when the joint is being made, because it will eventually reach the valve and cause irregular gas flow for some time.

Bench Tests.—The valve passed 12 cubic metres per hour of nitrogen and at least 40 cubic metres per hour of hydrogen (the maximum available at the test panel) with an inlet pressure of 300 atmospheres and exit pressure 60 atmospheres. The exit pressure remained steady within ±0·5 atmospheres at any given pressure setting for all flows. On closing the outlet, the exit pressure rose at a rate of about 10 atmospheres per hour, corresponding to a leakage of less than 1 litre per hour.

A large change of inlet pressure always caused a small change of exit pressure in the opposite direction due to the inlet gas pressure on the head of the small valve opposing the spring pressure. Thus a drop from 300 to 200 atmospheres on the inlet side caused a rise of between 0·5 and 1·0 atmospheres on the exit.

The valve lift was checked by a Mercer dial gauge mounted on the spring platform *S* and applied to the rod *N*. It was only about 0·001in for the flow of 10 cubic metres per hour of nitrogen.

Plant Performance.—Three downstream pressure regulators have run for four months on hydrogen, carbon monoxide and carbon dioxide with no maintenance except on one occasion when a steel chip was found in the valve. The regulators maintained their exit pressures accurately all the time except when the steel chip caused trouble.

Applications.—These regulators are used for feeding gases at constant pressures (up to 100 atmospheres) to small-scale plants when the supply pressure is much greater and perhaps variable. When gas has to be let down to a pressure below 10 atmospheres and controlled to closer limits than ±0·5 atmospheres, a second pressure regulator of the oxygen or acetylene type should be connected in series with this regulator. A bursting disc or relief valve must be connected between the two pressure regulators to prevent a dangerous rise in pressure if the low pressure outlet is closed. A downstream pressure regulator can also be used as a pilot to control a much larger pressure reducing valve.

Downstream Pressure Regulator for 350/100-300 Atmospheres

This device (Figs. 3 and 9) is similar in principle to the spring-loaded type but gas

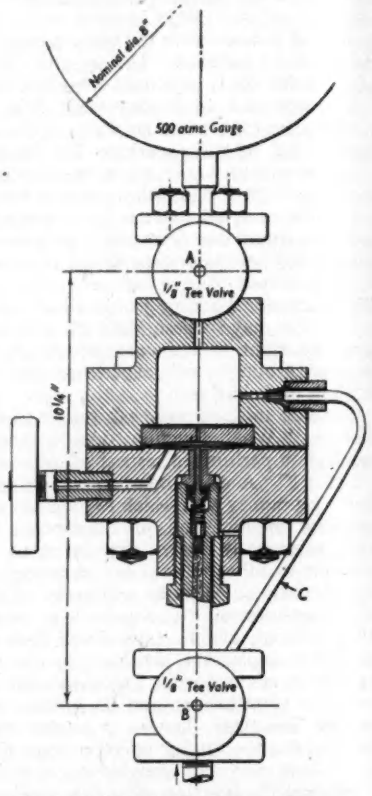


Fig. 3—Gas Loaded Downstream Pressure Regulator

taken from the inlet is admitted to the top of the diaphragm and isolated at the required pressure as a substitute for the spring. This design had to be adopted for the two reasons that a spring to balance 300 atmospheres would be very large, and such a spring would concentrate its load on the centre of the diaphragm while the opposing gas pressure was evenly distributed. The thin diaphragm would consequently be overstressed. With gas pressure loading the diaphragm can actually be made thinner than that of the spring-loaded design ($\frac{3}{64}$in instead of $\frac{1}{16}$in); its deflection is limited in both directions by the slightly concave surfaces above and below it.

Gas pressure is admitted to the upper vessel by the fine-adjustment "T"-valve *B*

† An attempt was made to dispense with the sleeve by putting the "Fluon" seat into a deep recess in the valve head and spinning the 18/8/Ti edge over it. Work-hardening prevented the formation of a sufficiently large turnover to hold the seat effectively.

and can be let down by valve *A*. The body of the regulator is made heavier than that of the spring-loaded one to suit the higher pressure and to accommodate the larger studs. The control pressure of the isolated gas varies with the temperature by about 0·4 per cent per 1 deg. Cent. For this reason slight adjustments are necessary from time to time and the instrument must be shielded from direct sunshine.

The diaphragm joints cannot be made of the self-sealing lens-ring type and it has

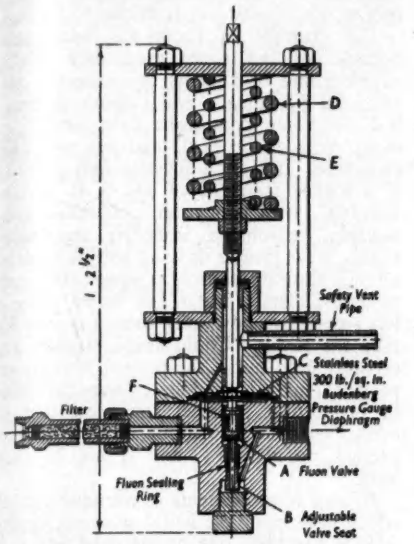


Fig. 4—Upstream Pressure Regulator, 0 - 30 Atmospheres

been found that there is sometimes a very slow loss of gas from the isolated vessel above the diaphragm. This can be completely eliminated by putting 8 to 10ml. of oil (S.A.E. 50 grade) in the vessel (but not with oxygen). No trace of oil can be found outside the joint even after prolonged use at 300 atmospheres.

It is important that the contact circles on opposite sides of the diaphragm should be equal in diameter, otherwise the diaphragm is deflected when the joint is tightened and the regulator will not work properly.

Remote Adjustment.—Remote adjustment can be arranged by separating valves *A* and *B* and the pressure gauge from the rest of the

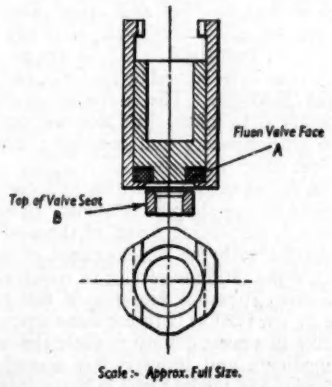


Fig. 5—Valve and Valve Seat for Upstream Pressure Regulator

instrument and placing them at the control point. If any gas at a sufficiently high pressure is already available at the control point then only one connecting pipe need be run (to replace pipe *C*).

Filters.—The filter requirements are the same as for the spring-loaded regulator.

Performance.—The characteristics of this regulator are almost identical with those of the spring-loaded type except that, as already mentioned, there is a pressure rise of about 0·4 per cent per 1 deg. Cent. rise of temperature. The regulator works equally well at all pressures from 30 to 300 atmospheres

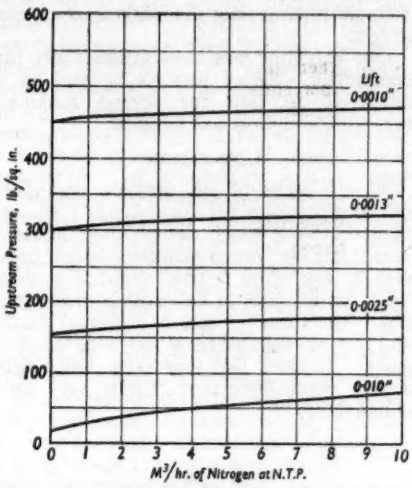


Fig. 6—Upstream Pressure Regulator, 30 Atmospheres

with inlet pressures up to 350 atmospheres, but is not generally used below 100 atmospheres because the spring-loaded type is cheaper. It might be thought that the gas loading pressure would be difficult to adjust accurately because of the small volume above the diaphragm. In practice there is no difficulty, however, in raising or lowering the pressure very slowly by means of valves *B* and *A*.

One regulator worked well on a pilot plant for ten months and gave very little trouble after initial filtering difficulties had been overcome.

Upstream Pressure Regulator 0–30 Atmospheres

Controllers are often required to maintain a steady delivery pressure from a small compressor by by-passing excess gas to the suction of the machine. A conventional pneumatic pressure controller can be used but is expensive, requires an external air supply, and is more complicated than the simple requirement justifies.

In appearance the new upstream pressure regulator (Figs. 4 and 7) is similar to the spring-loaded downstream type. Internally, however, the arrangment differs in that the

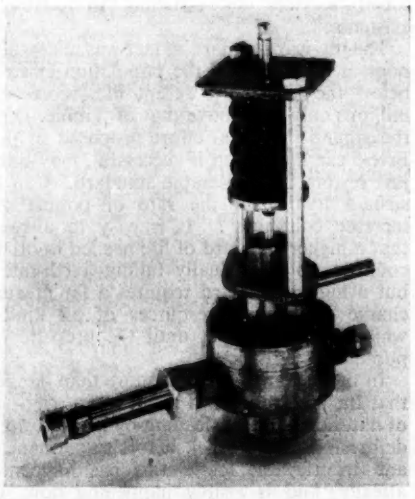


Fig. 7—Upstream Pressure Regulator, 0 - 30 Atmospheres

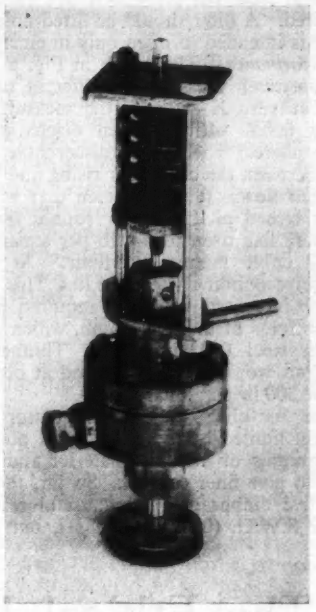


Fig. 8—Downstream Pressure Regulator, 350/20 - 100 Atmospheres

diaphragm is subjected to the upstream pressure and the valve is opened instead of closed by increasing pressure. The lower pressure drop (30 atmospheres being the maximum permitted by a sufficiently thin diaphragm to give enough valve opening) across the upstream regulator necessitates the use of a larger valve ($\frac{1}{16}$in bore, Fig. 5) and a corrugated diaphragm to give an increased valve

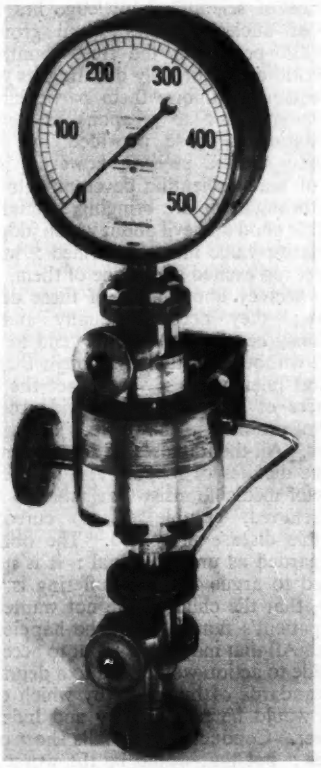


Fig. 9—Gas Loaded Downstream Pressure Regulator, 350/100 - 300 Atmospheres

lift. The "Fluon" valve ring *A* is lifted off the valve seat *B* by the diaphragm *C*, (Fig. 4) but is protected against excessive closing pressure (due to springs *D*, *E*) by the spring *F*.

The internal arrangement of this regulator permits dismantling for cleaning without

removal from the pipeline if this should be required. A filter should be fitted unless the valve is intended to open only in emergency.

Performance.—The graph in Fig. 6 shows the upstream pressure for different rates of flow at various settings, the measurements being taken with nitrogen discharging to atmosphere. There is no discernable deviation between the curves for rising and falling rates of flow. It will be seen that with the valve closed at 450 lb per square inch the pressure has risen to 470 lb per square inch at 10 cubic metres per hour. At 150 lb the corresponding rise is 25 lb. This is due to the increased valve lift required and to the stiffness of the diaphragm, which was of spring steel 0·037in thick. Thinner diaphragms would have to be used at pressures below 300 lb per square inch.

The usefulness of this regulator is at present limited by the difficulty of obtaining diaphragms of suitable material and thickness to give finer control. So far, the most sensitive diaphragm giving useful results is of 22 S.W.G. (0·028in) 18/8/Ti, but this is still rather stiff (pressure rise from 382 lb to 400 lb per square inch for a nitrogen flow variation of 0·5—10 cubic metres per hour). The only thinner diaphragm so far obtained was 0·010in thick and became permanently distorted at a pressure below 30 atmospheres. Suitable intermediate diaphragms are being sought.

One regulator was used satisfactorily for compressor delivery pressure control on a semi-technical unit for several months; very little attention was required.

Conclusion

A new series of gas pressure regulators has been produced for use at higher pressures than those for which designs have hitherto been available. They maintain the gas pressure at any given setting within very close limits for all rates of flow within their capacity. Their leakage rate is extremely small, and they are suitable for a very wide range of gases. Provided that they are installed with a very good filter they require very little maintenance.

The Ethical Dilemma of Science

By Professor A. V. HILL, C.H., O.B.E., F.R.S.

In his presidential address to the British Association, delivered on September 3rd in Belfast, Professor Hill discussed how far science has already contributed to human betterment, how far it has provided fresh problems, dangers and difficulties, and suggested ways in which all who are concerned with science can help, as citizens, to make sure that its results in fact are beneficial. Here we reprint abstracts from the address.

THE development which has brought most vividly to the public conscience to-day the ethical problems aroused by the advance of scientific knowledge lies in the field of nuclear physics; and groups of scientific people in the free countries of the world are vigorously debating its various consequences, among them particularly the secrecy attached to weapons as new and devastating as those provided by nuclear fission. Atomic physics, however, is only one of many scientific developments which have brought, or are bringing, a mixture of possible good and evil about which judgments of relative value must be formed: we must not get too excited about one of them. There is no secrecy about most of these developments; they occur gradually and continuously before our eyes, we tend to accept them without question as though they were natural phenomena: yet in fact the consequences of one of them provide the most solemn problem in the world. The dilemma is this. All the impulses of decent humanity, all the dictates of religion and all the traditions of medicine insist that suffering should be relieved, curable disease cured, preventible disease prevented. The obligation is regarded as unconditional: it is not permitted to argue that the suffering is due to folly, that the children are not wanted, that the patient's family would be happier if he died. All that may be so; but to accept it as a guide to action would lead to a degradation of standards of humanity by which civilisation would be permanently and indefinitely poorer. Conduct usually falls short of principles: but that would be the worst reason for abandoning principles altogether.

In many parts of the world advances in public health, improved sanitation, the avoidance of epidemics, the fighting of insect-borne disease, the lowering of infantile death-rates and a prolongation of the span of life have led to a vast increase of population. Not only is the population increasing, but in many places its rate of increase is still rising: and these processes will take so long to reverse that for many years to come the shortage of natural resources, particularly of food, is bound to provide increasing deprivation and disturbance. That provides the practical motive of the Colombo Plan. In India, a Government Planning Commission in a report of July, 1951, entitled "The First Five-Year Plan," has dared to face the facts. A doubling in the last thirty years of the survival rate (births minus deaths) has led to a rate of increase of nearly 1½ per cent per annum, a total of 5 million every year in a population of 360 million.

"With all the effort that the First Five-Year Plan will represent, it will be possible barely to restore by 1955–1956 the pre-war standards in regard to food and clothing. Increasing pressure of population on natural resources retards economic progress and limits seriously the rate of extension of social services so essential to civilised existence."

The pre-war standard in fact was miserably poor, a large part of the population existed below the level of a decent life, scores of millions only just above that of famine. Yet the gigantic national effort proposed in the Five-Year Plan, even if successful, may only just restore that miserable standard. Can it sustain it then if the rate of population increase continues? It is easy to answer that a higher standard of life has led in other countries to a gradually falling birth-rate: but a higher standard requires a far greater charge on natural resources of all kinds, which cannot be met until the pressure of population is reduced.

In the meantime there is more than danger that the emergency will result in an over-use of natural resources, leading by land erosion, deforestation and other factors to permanent and irretrievable loss: this has happened already, and is visibly happening now, in many parts of the world. In a special section on "Family Planning" the Indian Report recognises that "an alteration in population trends takes at least a few generations to materialise;" and steps are suggested for the education of public opinion on the need for limitation, and for experimental efforts to be made in the application of simple methods of birth control. For its wisdom and courage in acknowledging the gravity of the situation the Indian Planning Commission deserves every support: but the problem itself has not begun to be solved, and its consequences will dominate the development of India for many years; indeed, its gravity will continue to increase.

The example of India has been taken because of the sheer magnitude of the problem and because its seriousness is now admitted by humane and responsible men: but the same conditions exist already in many parts of the world and will soon exist elsewhere. It is not a question only of food: if a higher standard of life is to become universal, with education, communications, housing, reasonable amenities and public health, a far greater demand will be made on all such natural resources as power, chemicals, minerals, metals, water and wood. One is left wondering how long these can possibly take the strain. Could world supplies conceivably hold out if the present requirement per head, in the United States, were multiplied in proportion to meet the same demand everywhere—even without any increase of present population; and if so, for how long?

By vast improvements in communications, which have made the world so small, applied science has been one of the chief agents in the present ferment of social, political and economic thought. Can one urge, after the event, that the application was a mistake and that the majority of mankind could better have remained isolated and in ignorance? By making world war technically possible, applied science has helped to stir up national ambitions and social revolutions, which, if poverty and deficiency continue without hope, may lead to major world catastrophe. Should we therefore refuse to employ science in defence of liberty and resign outselves to a universal police state where no scruples are permitted? Are we, in scientific research, to say that some subjects may be investigated, but not others for fear of the consequences? Who, then, is to decide and by what international authority? And is it practical to insist that all scientific knowledge should be fully and openly disclosed, without secrecy or reservation of any kind, military or industrial? These are problems which cannot be solved by rhetoric, or by any simple formula. The purpose of setting them out is to make clear that we must face them with honesty and courage; for they will not solve themselves.

The dilemma is a real one, and cannot be resolved by any simple expedient. In another form it is perplexing many of those who are concerned with the development of nuclear physics, the ultimate service of which may be very great, possibly essential if our present type of civilisation is to continue when other sources of power dry up; while the benefits to medicine and industry are already substantial. But nuclear fission has released the threat of unprecedented violence, with the possible destruction of many millions of lives and the accumulated treasures, moral and material, of civilisation. The individual conscience may tell a man to have no part in it: that is easy enough, for there are plenty of other interesting things to do, but it does not solve the problem. Moreover, it is possible that defensive weapons, based on nuclear fission, but not of the type intended for mass destruction, can be developed which

would make armed aggression intolerably costly. What, then, of the abolition of secrecy? In principle, yes, for the historic and unique contribution of science to international good will has been in sharing knowledge regardless of race and frontier, and the chief satisfaction of scientific work, the condition of its fruitful development, is frank and free discussion. "Cast thy bread upon the waters, for thou shalt find it after many days" is wise and acceptable counsel in dealing with scientific knowledge: while "he that observeth the wind shall not sow and he that regardeth the clouds shall not reap" is as aptly applied to human relations as to agriculture. Every possible endeavour, therefore, should be made towards international agreement on sharing scientific and technical knowledge and controlling nuclear weapons: but this, like peace itself, is a concern of every citizen, not only of scientific people. It is hard enough to get international agreement in quite simple matters, such as the perilous state of the North European fisheries, where no secrecy is involved and little national prestige, and the scientific evidence is unequivocal: but we must go on trying.

Much scientific and technical advance has led to unexpected dangers and difficulties. Without our present knowledge of bacteriology and preventive medicine, gigantic armies could never be kept in the field, and land war on the recent scale would be impossible: is medical science, therefore, to be blamed for twentieth century war? The indiscriminate use of insecticides, by upsetting the balance of Nature, can quickly do more harm than good. Radio communication may be used for spreading lies and disorder as well as truth and good will. Developments in microbiology, in many ways beneficent, may be used in the future for biological warfare, with effects at present unpredictable; and control by international agreement and inspection might be very difficult. The list need not be multiplied; all are aware that every new benefit to mankind provides also its own dangers, either as unexpected consequences or by deliberate misuse. Science is not alone in this: liberty may lead to licence, religion can be used to inflame passions, laws can be exploited to protect wrongdoing. If scientists feel called upon to examine their consciences, so much the better; but they need not imagine that in this they are exceptional!

It has been debated whether "the scientific mind is fundamentally amoral." The real answer is that there is no such a thing as "the scientific mind." Scientists for the most part are quite ordinary folk. In their particular scientific jobs they have developed a habit of critical examination, but this does not save them from wishful thinking in ordinary affairs, or sometimes even from misrepresentation and falsehood when their emotions or prejudices are strongly enough moved. Their minds are no more amoral than those of surgeons, lawyers or scholars. As investigators most of them realise that their function would be stultified were they to introduce moral data into a scientific argument. A surgeon is not required, or indeed allowed, to consider whether it would be better for the world if his patient died under the operation, he has only to carry it out with skill, care and integrity: but it would be foolish to conclude that the surgical mind is amoral. The surgeon himself, as a human being, has to make moral judgments: but he does so outside the operating theatre. So it is with scientific people: like all good citizens, they must take account of ethical considerations, and the chief of these, as with other good citizens, are of integrity, courage and good will. Integrity forbids them to allow feelings of any kind to obscure facts, but that does not make them amoral: after all, integrity is the first condition of morality.

In the practical world of to-day complete abandonment of secrecy, in Government and industry, is out of the question. The advantages to international relations, and to general scientific progress, of the greatest possible freedom are evident; to these can be added the impossibility, in a free democracy, of keeping the best people unless the conditions of their work are congenial. If scientific men consistently avoid jobs which seem to them to fall short of reasonable freedom, they will force changes of organisation so that only necessary secrecy is maintained. The penalty of filling an organisation, governmental or industrial, with second-rate people, cheerfully amenable to unnecessary restrictions, is far too evident in its result on efficiency to be tolerable for long. The cure, therefore, is largely in scientists' own hands. In this, as in many other aspects of their work, moral considerations come in, and the only way to resolve the dilemma which is in so many minds is to discuss it frankly. To neglect it altogether is not amoral but immoral; it is the duty of all of us as citizens to consider the ethical basis of our work.

To-day, when the public importance of science and its popular esteem may turn some people's heads, it is well that scientists should realise that the prestige of science is not their personal property, but a trust which they have an obligation to pass on uncompromised to their successors. The popularising of genuine science is an important public service; we should all be ready to take our part in it according to our powers: but to use the general prestige of science as a bait to attract attention to pronouncements on other topics—for example on politics or religion—is a disservice both to science and the public.

Some seventeen hundred years ago there crystallised out, from many centuries of experience of the human problems and ethical necessities of medicine, the so-called Hippocratic Oath. The obligation of integrity and trust; the insistent claim of suffering; the care of mothers and children; solicitude for the old and weak; the sanctity of human life; these are as vital a part of medical tradition as its science and its art. To-day science finds itself, unexpectedly and without those centuries of tradition and experience, in a position no less important to the community than medicine: and its ethical principles have not yet clearly emerged.

Every candidate for admission to the earliest of American learned associations was required to answer "Yes" to the question, "Do you love truth for truth's sake, and will you endeavour impartially to find . . . it for yourself and communicate it to others?" That affirmation might have its place in a modern scientific version of the Hippocratic Oath. But again the same dilemma arises—"endeavour impartially . . . to communicate it to others." Apart altogether from considerations of national security, in many fields to-day much of the best research is done, and done increasingly, in industrial laboratories. Those who have seen and admired such work and the people who do it, cannot but applaud the foresight which made it possible. But if all the results are to be communicated at once and impartially to others, could directors and shareholders be reasonably expected to continue their support? Indeed, if an industry were nationalised could it afford to give away its secrets to competitors abroad? Not in any real world, in which a nation must remain solvent and industry must depend for success on the rapid application of new knowledge. The dilemma must be met by reasonable compromise, of which perhaps the most hopeful sign to-day is that many of the directors of industry come up through research departments. A friendly and familiar contact between management and research, and between industrial and outside scientists, can reduce this particular dilemma to manageable size.

A graver problem is provided by research under Government, when considerations of security come in. In the emergency which became evident in 1935, the secret development of radar for purposes of air defence aroused no obvious pangs of conscience; and many other developments come in that class. But the surest of military maxims is that counter attack is an essential part of defence; to limit scientific methods to defensive weapons would be to ensure defeat, indeed it is quite impracticable. But let us be realists; so long as offensive weapons may be used, the part played by the scientist is no more immoral than that of the engineer, the workman, the soldier or the statesman, and the attitude of "holier-than-thou" is unbecoming. We all bear, as citizens, an equal responsibility. But is it practical to suggest that all scientists in all countries should agree, and hold to their agreement whatever happens, to take no part in research on offensive weapons, or at least should endeavour impartially to communicate its results to others? The answer is evident. There are individuals in all free countries who find such work intolerable. In those countries their scruples are respected and they are at liberty to do something else; but let them not imagine that the problem is solved that way, or that those who think otherwise are necessarily stupid or immoral. The first condition of freedom is freedom of conscience, and the scientist has the same right to that as any citizen: but freedom does not extend to giving away other people's property, whether of goods or knowledge.

Is there really then any special ethical dilemma which we scientific men, as distinct from other people, have to meet? I think not, unless it be to convince ourselves humbly that we are just like others in having moral issues to face. It is true that integrity of thought is the absolute condition of our work, and that judgments of value must never be allowed to deflect our judgments of fact. But in this we are not unique. It is true that scientific research has opened up the possibility of unprecedented good, or unlimited harm, for mankind; but the use that is made of it depends in the end on the moral judgments of the whole community of men. It is totally impossible now to reverse the process of discovery: it will certainly go on. To help to guide its use aright is not a scientific dilemma, but the honourable and compelling duty of a good citizen.

ACTIVITY AT UNITED KINGDOM AERODROMES.—Air transport movements at United Kingdom aerodromes in July this year totalled 25,850, which was 9·9 per cent above the figure for July, 1951. Passengers handled totalled 414,224, an increase of 15·1 per cent on the number for July last year. Freight on and off-loaded at 4416·4 short tons showed a decrease of 15·1 per cent. Post Office mail set down and picked up decreased from 1055·6 to 1038·1 short tons. At London Airport there were 3999 air transport movements (an increase of 2·5 per cent on July, 1951) and passengers handled totalled 102,832 (an increase of 5·1 per cent). Northolt recorded 5366 transport movements (an increase of 13·1 per cent), while passengers handled increased by 10 per cent to 101,637. Other airports at which passenger traffic increased considerably over July last year were Prestwick, 23,369 (43·6 per cent increase); Manchester (Ringway), 26,308 (38·9 per cent increase); and Isle of Man (Ronaldsway), 24,875 (20 per cent increase). Jersey airport handled 44,378 passengers, an increase of 31 per cent; and Guernsey 18,660, an increase of 37·2 per cent.

Electromagnetic Couplings and Gearbox on M.V. "Surrey"

The motor vessel "Surrey," built by Alexander Stephen and Sons, Ltd., for the New Zealand Shipping Company, is an 8400-ton, single-screw ship powered by two nine-cylinder Sulzer engines, each developing 4500 h.p. at 225 r.p.m. They drive the single propeller shaft through the medium of a B.T.H. twin-pinion gearbox, which, having a reduction ratio of 2·23 to 1, gives a propeller speed of 100 r.p.m. at full power. The engines are connected to their respective pinions through B.T.H. electromagnetic couplings, which, relying for their operation on development of the principle of the conventional induction motor, give a small slip between the driving and driven portions so that the actual pinion speed at nominal full power is abo at 223 r.p.m. Some details of the couplings and gearbox are given here.

Electromagnetic Couplings

THE primary function of electromagnetic couplings follows from their inherent elastic and damping properties, which reduce the magnitude of the torsional oscillations transmitted from the engines to the gears to a value such that tooth separation does not occur and the risk of damaging the gears is thus substantially reduced. A secondary but useful characteristic of the couplings is the improvement which they give to the ease of operating the engines. By running one engine in the "ahead" direction and the other in the "astern," the screw can be turned in the required direction simply by energising the appropriate coupling. Using this method, power can either be applied to or removed from the screw more quickly than by the normal method. Another advantage is that less starting air is used, and the adverse effects on the engine cylinders due to repeated influxes of cold air are reduced. If one engine is already running, no starting air at all will be required if the second is to be run up in the same direction, since this may be done simply by energising the two couplings. If both engines are running ahead, and it is required to "go astern," the couplings are de-energised and the engines stopped, whereupon they may be started in the astern direction under no-load and the power applied to the screw by reapplying the excitation to the couplings.

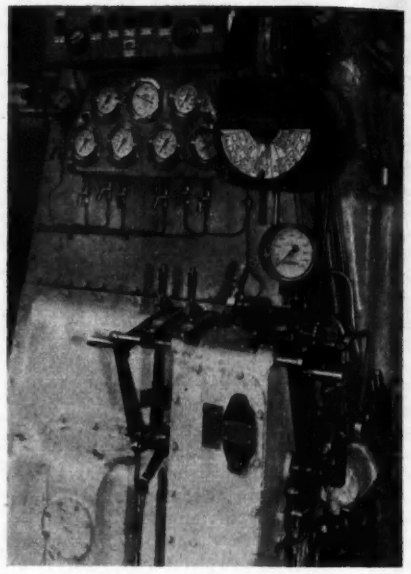
Our illustration of the complete installation set up for test in the engine builders' works shows the arrangement of the equipment. The two couplings are identical, each consisting of two concentric rotating members, one mounted on the engine crankshaft and the other overhung from the pinion shaft. The couplings themselves have no separate bearings.

Each coupling consists of an outer and an inner member; the outer member is a welded steel ring which forms a magnetic yoke, as illustrated on page 315. Thirty-two non-laminated poles, of high permeability steel located around the inner periphery, secured by dowels and set screws, carry the excitation winding, which consists of rectangular copper strip wound on edge with treated asbestos between the turns and insulated with mica protected with varnished press-board. The coils are supported in position between moulded insulation end flanges and the whole insulated assembly complies with the standards of class "B" insulation. The couplings are self-ventilating, drawing air into the sides and discharging it through the holes in the periphery. At coupling speeds below 150 r.p.m., the excitation is reduced in order to avoid the risk of overheating which might be caused by the reduction in the quantity of ventilating air flowing.

A steel disc with stiffening ribs is welded to one side of the coupling yoke and the centre is bored and faced to form the coupling flange. For leading the magnetising current to the windings, two phosphor-bronze slip-rings are provided and they work in conjunction with a brush gear assembly which is mounted on the adjacent bearing housing.

The inner member consists of a segmental rotor core built up from punchings of low hysteresis steel, enamelled before assembly and clamped between steel end flanges. The core is mounted on a fabricated steel spider which carries a coupling flange in a similar fashion to the outer member. The inner member carries a double squirrel-cage winding, the upper bars of which are of high-resistance alloy and the lower bars of copper. Each cage has its own short-circuiting connections which take the form of copper rings, silver soldered to the bars of the cage windings. There is no insulation between the windings and the punchings, a detail which assists good conduction of heat away from the windings.

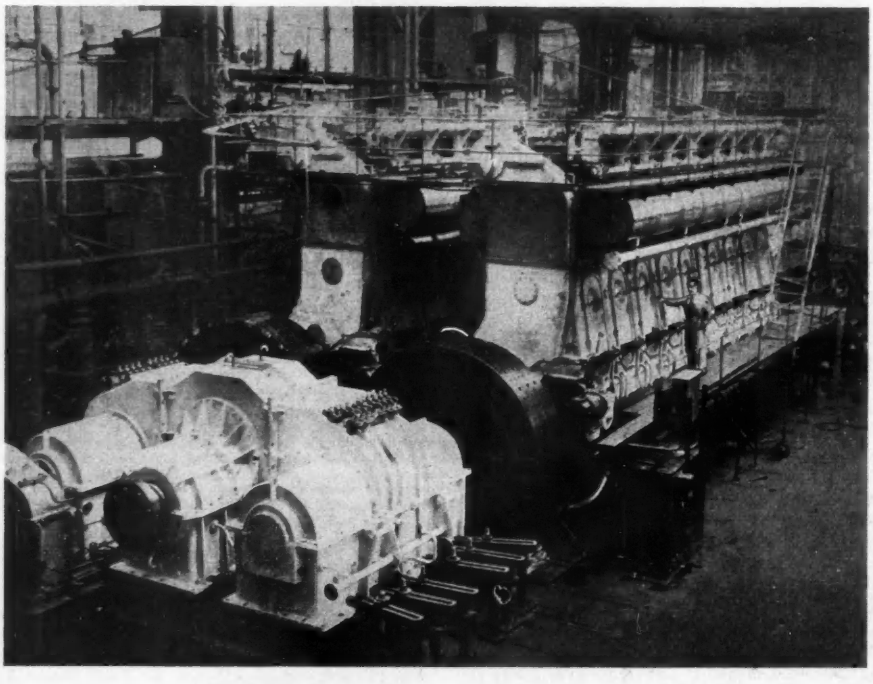
The coupling control gear is mounted on an insulated panel housed in a steel drip-proof cubicle. On the panel are the main cam-operated contactors for the excitation of the couplings, the coupling tripping circuits and fuses, also the electronic time-switch and Klaxon relay which comes into operation if the excitation be left on when the couplings are stationary. Four field-discharge rectifiers for each coupling are mounted on top of the cubicle together with the series resistances for varying the excitation applied to the outer members. Separate from the control cubicle and mounted near the engine gauge board is an instrument panel which carries the ammeters indicating the excitation current supplied to each coupling, various warning lamps, and the Klaxon cut-out switch.



Engine Control Pedestal

The engine control pedestal illustrated herewith carries the two main control levers, one for each coupling. The excitation current, amounting to about 40kW for each, is supplied from the ship's main d.c. system through the main switchboard and the coupling control cubicle. The main control levers have three positions:—(*a*) off, in which no excitation is applied; (*b*) position 1, in which reduced excitation is applied; (*c*) position 2, in which full excitation is applied.

The degree of excitation corresponding to position 1 was adjusted as a result of experience during the trials to a value at which the torque imposed on the engines during manœuvring could be allowed for by the governors without risk of stalling. In addition to the excitation warning device, already mentioned, various interlocks include one to prevent the engines from being started while the turning gear is engaged.

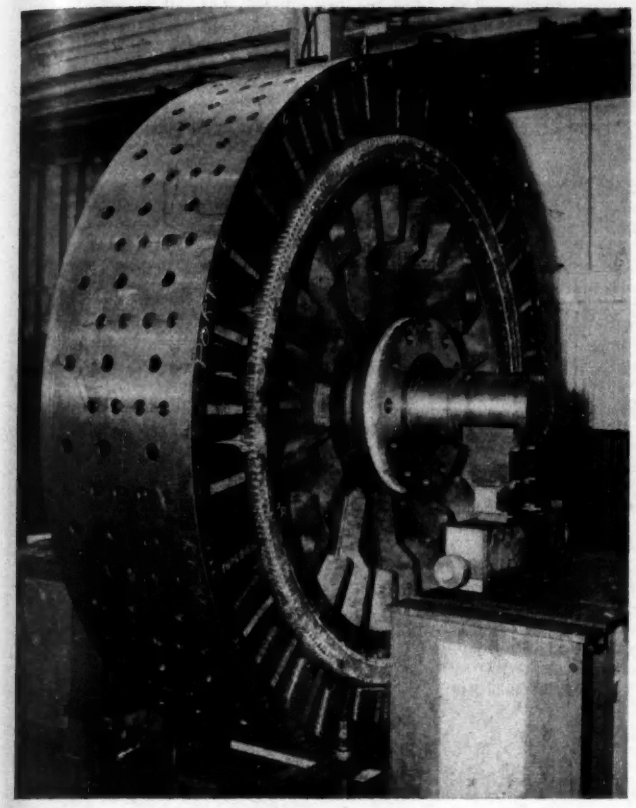


Engines, Electromagnetic Couplings and Gearbox on Works Test

Gearbox

The fabricated gearbox is a twin-pinion, single-reduction unit, the case being a fabricated structure consisting of a double-walled bottom half-casing with thin-walled top and bottom covers which are sectionalised to facilitate inspection and maintenance. Integral with the bottom half-casing are the main bearing oil supply pipes, and the main thrust-bearing seating. The use of a shallow bottom half-casing has the merit that the journal and thrust bearings of the gearbox are brought as close as possible to the holding-down bolts which secure the assembly to the ship's seatings, thus forming a rigid support

for the gears. Another virtue of this arrangement is that, during shop trials of the complete equipment, the whole set can be erected much closer to the floor than would be possible with a full depth gear case. As illustrated on this page, the two pinions mesh with the main wheel at 6ft centres and lie in the same horizontal plane. Each pinion assembly consists of two shafts and a gear type coupling, but an inner shaft, supported in its own bearings, carries one member of the electromagnetic coupling overhung at the forward end and connected at the aft end through the gear type coupling to a quill shaft carrying the pinion. The quill shaft is also supported in its own bearings and is thus relieved of the overhung load of the coupling and although the inner shaft is located axially the pinion is free to move through the medium of the gear type coupling. These arrangements ensure a good alignment between the pinions and the wheel, with consequent accurate meshing of the gear teeth. This fact was demonstrated by the perfect bedding over the whole 36in face width obtained on both pinions after the first full-load run. The gear wheel is also of fabricated construction, the shroud being of forged steel. The gear wheel hub has a parallel bore and the wheel is pressed on to the slow-speed shaft. Integral with the slow-speed shaft is the main thrust collar, 36in in diameter, which also serves to locate the gears.



Electromagnetic Coupling

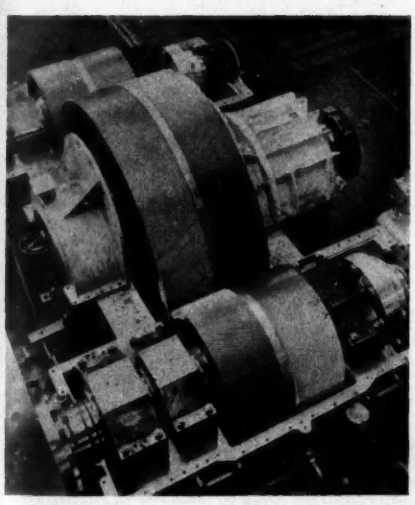
The main gearbox bearings are mild steel shells with "Glacier" thin white metal linings, the pinion bearings measuring 18½in by 16in and the slow-speed shaft bearings 19in by 18in.

The double-helical gear teeth, which have a normal pitch of ½in, were cut in the B.T.H. Works at Rugby on solid table hobbing machines which are housed in temperature-controlled cubicles in the company's gear factory. The pinions have 162 teeth, the wheel 361 teeth, and the helix angle is approximately 30 deg.

Lubrication of the gear teeth is effected by overhead sprays only, a total number of sixteen (four per face per side) being fitted. Each sprayer has its own filter and sight-flow indicator, and is retractable; it can be removed without shutting off the main oil supply. All the bearings are fed with oil by internal pipes, the only external pipes being the main supply pipes from the header tank. Gauge boards on each side of the gearbox show the bearing temperatures and oil manifold pressures. The turning gear is also lubricated from the main gearing oil system.

The turning gear is a triple-reduction unit giving the propeller shaft $^1/_5$ r.p.m. Power is supplied by a 3 h.p., 750 r.p.m. motor, and the gears provide a reduction of 1800/1 through a 50/1 worm gear and a 36/1 double-reduction spur gear. Concentric with the third reduction gear wheel is a sliding dog clutch which, under the control of a handwheel, engages with a similar clutch on the end of the port pinion shaft. The operating handwheel is interlocked to prevent the main engines from being started with the clutch engaged and also to prevent the turning gear motor from being started with the handwheel locked in the "out" position.

The overall efficiency of the complete coupling and gearbox installation is of the order of 96·5 per cent.



Gearbox with Top Half Casing Removed

The Unit in Operation

The characteristic (slip-torque) curves of the electromagnetic couplings (torque expressed as a percentage of full-load engine torque, plotted against slip expressed as a percentage of full speed, for the values of excitation given by positions 1 and 2 of the control levers) show that at zero slip, when no current will be induced in the squirrel-cage windings since there will be no cutting of the flux set up by the outer member, no torque will be transmitted. At 100 per cent slip, the torque transmitted at position 2 of the excitation control is about 100 per cent of full-load torque, and at position 1 is about 55 per cent of full-load torque. When the couplings are running at full power and speed there is a slip of about nine-tenths of 1 per cent between the two members, which corresponds to an actual slip of about 2 r.p.m.

The speed at which manœuvring is carried out, as described briefly at the beginning of this account, was chosen on the trials as 110/115 r.p.m., the port engine running ahead and the starboard astern. On either coupling control lever being engaged at position 1, the propeller accelerated steadily from rest to approximately 40 r.p.m., in eight to ten seconds.

The procedure for going astern in an emergency after a period of ahead running, as distinct from when manœuvring, which has already been mentioned, is for the engine speed to be reduced and the excitation removed from the couplings. Next, the engines are stopped, then restarted in the opposite direction and the excitation applied to the couplings again. During the trials, a "full-astern" order was received with the shaft running ahead at 90 r.p.m. The engine speed was reduced and the coupling excitation removed. The engine starting levers were then removed to the "off" position and held for ten seconds before the admission of astern air. The engines were then run up astern, the coupling levers moved to position 1, and thence to position 2 as the engine fuel was increased. The time between the receipt of the order "full astern" and the bringing to rest of the shaft was forty-two seconds. in sixty-one seconds from receipt of the order the shaft speed was 90 r.p.m. astern.

During the sea trials the equipment functioned satisfactorily, and the "Surrey" sailed from the Clyde on July 5th.

Plastic Collapse Loads for Plane Frames*

By B. G. NEAL† and P. S. SYMONDS‡

In suitable instances the application of plastic design methods to plane frames of ductile material, such as mild steel, leads to more rational and economical designs. These design methods are based on the calculation of the loads at which a structure collapses owing to excessive plastic deformation. Such collapses occur when a sufficient number of plastic hinges have formed to transform the structure into a mechanism, so that deflections can continue to grow, due to rotations of the plastic hinges, while the loads remain constant. In this paper the theoretical basis of a new technique for determining plastic collapse loads is discussed and typical calculations for a pitched-roof portal frame are given.

Plastic design methods have been developed with a view to providing a more rational and economical approach to the design of framed structures whose members possess a high degree of ductility.[1] The methods are applicable to cases in which the members of a frame possess a relation between bending moment and curvature of the form illustrated in Fig. 1. The important features of this type of relation are :—

(i) If the curvature increases indefinitely, the bending moment tends to a limiting value $\pm M_p$, termed the fully plastic moment, regardless of the previous history of loading.

(ii) An increase of curvature is always accompanied by an increase of bending moment of the same sign, unless the bending moment has attained its fully plastic value.

The behaviour of mild steel beams conforms quite closely to these assumptions, and experimental investigations have confirmed the validity of applying plastic methods of design to framed structures of mild steel.[2] As yet, little consideration has been given to the possibility of applying the plastic methods to framed structures of other ductile materials, such as certain of the light alloys.

When the fully plastic moment is attained at a particular cross-section of a member, the curvature at this cross-section is indefinitely large, so that a finite change of slope can occur over an indefinitely short length of the member at this cross-section. The member therefore behaves as though a hinge existed at this cross-section, rotation of the hinge being possible only when resisted by the fully plastic moment. This concept of a plastic hinge was first introduced by Maier-Leibnitz,[3] and it is of great

* Paper presented at the Fourth Congress of the International Association of Bridge and Structural Engineering.
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value in considering the behaviour of framed structures under load.

For the sake of simplicity, consider first a framed structure subjected to several loads, each load maintaining the same proportion to each of the other loads. If the loads are steadily increased, the structure will first support the loads by wholly elastic action. Eventually a plastic hinge will form at the most highly stressed cross-section. If the loads are increased still further, this plastic hinge will rotate under a constant bending moment, its fully plastic moment, and further plastic hinges will form and rotate in other parts of the structure. Finally, a condition will be reached in which a sufficient number of plastic hinges have formed to transform the structure into a mechanism. The structure will then continue to deform to an indefinite extent while the loads remain constant, until the geometry of the structure is changed

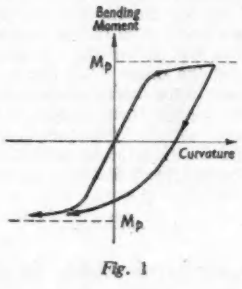

Fig. 1

appreciably. Such changes may either check the growth of the deflections, or cause a catastrophic collapse by accentuating the effects of the loads. In practice, strain-hardening also checks the growth of deflections. The theoretical condition of indefinite growth of deflection under constant loads is termed plastic collapse.

The methods of plastic design are used in conjunction with a load factor. The structure is designed so that the most unfavourable combination of the working loads, when multiplied by the chosen load factor, would just cause a failure by plastic collapse. This procedure is justifiable even when the loads do not necessarily maintain the same proportions to one another, for it has been shown that plastic collapse of a structure will occur at the same set of loads regardless of the sequence in which the individual loads were brought up to their collapse values. It is clear that the load factor has a very precise meaning in plastic design, for it represents the margin of safety which is provided against an actual physical failure of the structure.

Several methods for computing plastic collapse loads have been suggested.[4,5] These methods have been capable, in principle, of determining plastic collapse loads for framed

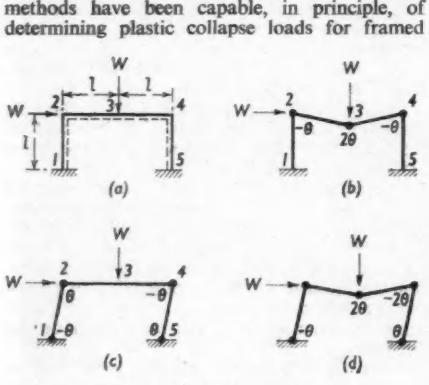

Fig. 2

structures of any degree of complexity. In practice, however, their application has been limited by the amount of time required for the necessary computations. In the present paper a method is presented which enables plastic collapse loads and their corresponding mechanisms to be determined very simply. The method consists essentially of building up the actual collapse mechanism from a certain number of independent components, which are termed the independent partial collapse mechanisms. Corresponding to any mechanism which is being investigated, a value can be found for the applied load by applying the principle of virtual work.[6] It has been shown that the correct collapse mechanism is the one to which there corresponds the smallest possible value of the applied load. The method consists therefore of combining the independent partial collapse mechanisms in a systematic manner in order to reduce the corresponding value of the applied load to its least possible value. In order to explain and justify the method, a simple example will first be discussed. Detailed calculations will then be given for a single-bay pitched-roof portal frame, and the calculations for a three-bay pitched-roof portal frame will also be outlined. Calculations for a two-bay, three-storey rectangular frame have been given elsewhere.[7]

The rectangular portal frame shown in Fig. 2 (*a*) will be used as a basis for the discussion of the method. All the joints of this frame are assumed to be rigid, and the feet of the stanchions are rigidly built in. The dimensions of the frame are as shown, and horizontal and vertical loads W are applied at the positions indicated in the figure. The fully plastic moment of each member is M_p, and the problem is to find the value of W which causes failure by plastic collapse.

For this particular type of structure it is known that there are only three possible collapse mechanisms, and these mechanisms are shown in Figs. 2(*b*), 2(*c*) and 2(*d*). In these figures the magnitudes of the plastic hinge rotations are all shown in terms of a single parameter θ. For reference, the signs of the plastic hinge rotations are also given, although in the technique to be described there is no need to take account of these signs. The sign convention adopted is that a hinge rotation is positive if the hinge is opening when viewed from inside the frame.

For each mechanism it is possible to calculate a corresponding value of W by applying the principle of virtual work in the special form

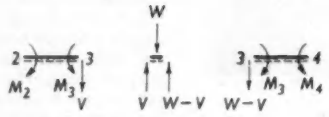

Fig. 3

that the virtual work done by the applied loads during a small displacement of the mechanism is equal to the virtual work absorbed in the plastic hinges. Considering the mechanism of Fig. 2(*b*), for example, it is seen that during the small mechanism displacement shown, the horizontal load W does no work and the vertical load W, displaced through a distance $l\theta$, does virtual work $Wl\theta$. To calculate the virtual work absorbed in the plastic hinges, it is noted that the work absorbed in any individual hinge is always positive. Since the fully plastic moment is M_p everywhere in the frame, the virtual work absorbed in the plastic hinges is at once seen to be $4\theta M_p$, since the total rotation of all the plastic hinges is 4θ. Applying the principle of virtual work :—

$$Wl\theta = 4\theta M_p, \text{ or } W = 4\frac{M_p}{l} \quad . \quad . \quad . \quad (1)$$

Similar calculations for the mechanisms of Figs. 2(*c*) and 2(*d*) are readily made. The results of these calculations are :—

Fig. 2 (*c*): $Wl\theta = 4\theta M_p$, or $W = 4\frac{M_p}{l}$ . . . (2)

Fig. 2 (*d*): $2Wl\theta = 6\theta M_p$, or $W = 3\frac{M_p}{l}$ . . . (3)

The correct collapse mechanisms can now be distinguished by applying what has been termed the *kinematic principle* of plastic collapse.[6,8] This principle states that : " For a given frame and loading, the correct collapse mechanism is the mechanism to which there corresponds the smallest possible value of the applied loads." For the particular problem of Fig. 2(*a*) it follows that the actual collapse mechanism is the mechanism shown in Fig. 2(*d*), which yields the lowest value of W, namely $3M_p/l$.

Examination of Figs. 2(*b*), 2(*c*) and 2(*d*) reveals the fact that the mechanism of Fig. 2(*d*) is a direct combination of the mechanisms of Figs. 2(*b*) and 2(*c*), in the sense that the displacements and plastic hinge rotations of this mechanism are obtained by summing the corresponding quantities for the mechanisms of Figs. 2(*b*) and 2(*c*). In fact, as will be seen later, these latter two mechanisms are the independent partial collapse mechanisms for this structure and loading. In general, all possible collapse mechanisms can be formed by combining the independent partial collapse mechanisms. In the simple problem under consideration there is, of course, only one possible combination to be investigated.

The particular feature of the combination of the independent mechanisms of Figs. 2(*b*) and 2(*c*), which is of interest is that for both these mechanisms the corresponding value of W was $4M_p/l$, whereas for the mechanism of Fig. 2(*d*) which resulted from their combination the value of W was only $3M_p/l$. This reduction

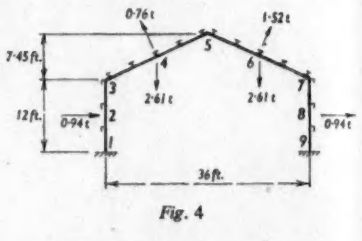

Fig. 4

of W is due to the cancellation of the plastic hinge at the cross-section 2 which occurs when the mechanisms are combined. When the two mechanisms are superposed, the virtual work done by the loads in each case may be added to obtain the virtual work done in the resulting mechanism. However, to obtain the virtual work absorbed in the plastic hinges in the resulting mechanism, work $2\theta M_p$ must be subtracted from the sum of the virtual work absorbed in the two independent mechanisms. This is to account for the term θM_p which was included in the virtual work absorbed in each of these mechanisms for the plastic hinge at the cross-section 2, which disappears as a result of the superposition. The virtual work equation for the resulting mechanism is thus obtained by adding equations (1) and (2), and subtracting $2\theta M_p$ from the resulting work absorbed in the plastic hinges, giving :—

$$Wl\theta + Wl\theta = 4\theta M_p + 4\theta M_p - 2\theta M_p$$

or

$$2Wl\theta = 6\theta M_p,$$

which was previously obtained as equation (3).

In general, the technique for combining the independent mechanisms thus consists in selecting pairs of independent mechanisms which themselves yield low values of W, and which

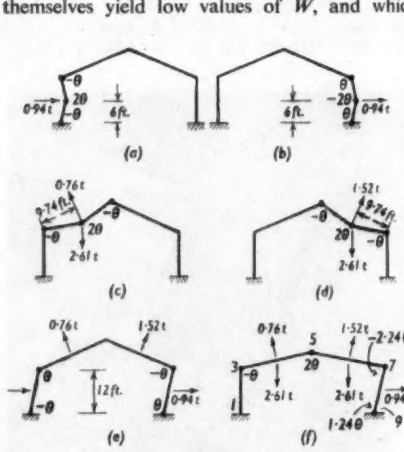

Fig. 5

can be combined so as to cancel a plastic hinge. Such a combination may, as has been seen, result in a value for W which is lower than the value corresponding to either of the mechanisms which were combined. Even in complicated problems, the combinations to be tried are usually

small in number, so that a solution can be obtained with great rapidity.

It is, of course, essential to start an analysis with the correct number of independent mechanisms. In fact, the number of independent mechanisms is always equal to the number of independent equations of equilibrium for the frame. To justify this statement, it is necessary to consider the statics of the illustrative example of Fig. 2(*a*), although it should be stressed that in actual applications of the technique there is no need to write down the equations of equilibrium. However, it is recommended that solutions should always be checked by statics, making use of the *principle of uniqueness of solution*,[6,8] which states that : " If a sufficient number of plastic hinges occur in a frame to transform the frame into a mechanism, and if a bending moment diagram can be constructed for the frame in which the fully plastic moment occurs at each plastic hinge position, then the corresponding load is the correct collapse load if the fully plastic moment is not exceeded anywhere in the frame." Examples of this form of check are given later in the paper.

The Equations of Equilibrium.—The equations of equilibrium for the frame illustrated in Fig. 2(*a*) are written down most conveniently in terms of the bending moments at the five cross-sections numbered from 1 to 5. It will be seen from this figure that when these five bending moments are known, the bending moment distribution for the entire frame is determined, for between any adjacent pair of these cross-sections the shear force is constant, so that the bending moment must vary linearly along the length of the member. These five bending moments are denoted by M_1, M_2, . . . M_5, the suffix indicating the relevant cross-section. The sign convention adopted for these bending moments is that a positive bending moment causes tension in the fibres of a member adjacent to the dotted line in Fig. 2(*a*).

This frame has three redundancies, for if a cut is imagined to be made at section 1, for example, and the values of the shear force, thrust and bending moment at this section are known, the entire frame becomes statically determinate. These three quantities can therefore be regarded as the redundancies of the frame. Since there are five unknown bending moments, it follows that there must be two independent equations of equilibrium.

The first of these equations of equilibrium expresses the fact that the vertical load W is carried by the shear forces in the horizontal member 234. Fig. 3 shows the relevant forces and bending moments, the load W being carried by a shear force V in the member 23 and a shear force $W—V$ in the member 34. Taking moments for the equilibrium of the members 23 and 34, it is found that

$$M_3-M_2=Vl$$
$$M_3-M_4=(W-V)l$$

On adding these equations to eliminate V, it is found that

$$2M_3-M_2-M_4=Wl \quad . \quad . \quad . \quad (4)$$

In a similar way, an equation expressing the fact that the horizontal load W is carried by the shear forces in the vertical members 12 and 45 may be found. This equation is

$$M_2-M_1+M_3-M_4=Wl \quad . \quad . \quad . \quad (5)$$

Equations (4) and (5) constitute the two independent equations of equilibrium.

In the mechanism of Fig. 2(*b*) plastic hinges have formed at the cross-sections 2, 3 and 4, so that the magnitude of the bending moment at each of these cross-sections is M_p. Having regard to the sign convention, these bending moments are

$$M_2=-M_p, \quad M_3=M_p, \quad M_4=-M_p$$

When these values are substituted in equation (4) a value for W is immediately found, this value being $W=4M_p/l$.

It will be seen that the mechanism of Fig. 2(*b*) corresponds to equation (4) in the special sense that in this mechanism each of the bending moments appearing in equation (4) takes on its fully plastic value, and that the sign of each bending moment is such as to give rise to the largest possible value of W. In a similar way, the mechanism of Fig. 2(*c*) may be said to correspond to equation (5). If each of the bending moments appearing in equation (5) is given its fully plastic value, and the sign of each bending moment is such that the largest value of W is obtained, the following values are found :—

$$M_1=-M_p, \quad M_2=M_p, \quad M_4=-M_p, \quad M_5=M_p.$$

These are the fully plastic moments appearing in the mechanism of Fig. 2(*c*).

To generalise, it may be said that any mechanism corresponds in this special sense to a particular equation of equilibrium. It follows that for any particular frame and loading the number of independent mechanisms will be equal to the number of independent equations of equilibrium. In the particular example under consideration there are only two independent equations of equilibrium, namely, equations (4) and (5) and any other equation of equilibrium must be obtainable by combining these two equations. Correspondingly, it follows that any possible mechanism will be found to be a combination of the mechanisms of Figs. 2(*b*) and 2(*c*). In this particular example there is only one possible combination of these mechanisms, which is illustrated in Fig. 2(*d*). The equation of equilibrium which corresponds to this mechanism is obtained by adding equations (4) and (5) so as to eliminate M_3, giving

$$2M_3-M_1-2M_4+M_5=2Wl \quad . \quad . \quad (6)$$

This addition corresponds to the superposition of the mechanisms of Figs. 2 (*b*) and 2(*c*). The bending moments at the plastic hinges may be seen from this equation, or from the mechanism of Fig. 2(*d*), to be

$$M_1=-M_p, \quad M_3=M_p, \quad M_4=-M_p, \quad M_5=M_p,$$

and the corresponding value of W is $3M_p/l$.

For convenience of discussion, the loads have previously been referred to as the variables, whereas in an actual design the loads will be given quantities and the problem is to find the

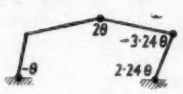

Fig. 6

required fully plastic moments of the members. When viewed in this light, the problem just discussed amounts to determining the *greatest* value of M_p, rather than the least value of W, corresponding to any possible mechanism, for it is the quantity Wl/M_p which is determined for any particular mechanism by a virtual work analysis, and minimising W for given values of M_p and l amounts to maximising M_p for given values of W and l.

To summarise, then, the proposed method is as follows :—

(1) Determine the correct number of independent mechanisms by calculating the number of independent equations of equilibrium.

(2) Calculate the required values of the fully plastic moments of the members by virtual work for these independent mechanisms.

(3) Investigate combinations of these mechanisms so as to maximise the required fully plastic moments.

(4) Check the solution by constructing a bending moment diagram.

An application of the method to a single-bay pitched-roof portal frame will now be given in detail, followed by a brief indication of the application of the method to a three-bay pitched-roof portal frame.

Pitched-Roof Portal Design

As an illustration of the practical application of the proposed method of design, typical calculations for a pitched-roof portal frame will now be given. The dimensions of the frame are as indicated in Fig. 4, the roof slope being 22½ deg. ; the working loads on the frame are also shown. These working loads, which are given in tons, are assumed to be spread uniformly over the purlins and sheeting rails shown in the figure. Of these loads, the vertical loads of 2·61 tons, acting on each rafter, are due to dead and superimposed (snow) loads, and the remaining loads are wind pressures and suctions. The frame is to be designed to a load factor of 1·75 for the case in which only the dead and superimposed loads are acting, and to a load factor of 1·4 for the case in which the wind loads are also acting. Each member of the frame will be taken to have the same cross-section, with a fully plastic moment M_p.

Design for Dead, Superimposed and Wind Loads.—The first design case which will be considered is the design to a load factor of 1·4 for the case in which the wind loads are acting in conjunction with the dead and superimposed loads. The first step is to decide how many independent partial collapse mechanisms must be considered. The number of such mechanisms for any given frame and loading has been shown to be equal to the number of independent equations of equilibrium. It is therefore necessary to calculate the number of independent equations of equilibrium, and this is done most conveniently by counting the number of bending moments which are needed to specify the bending moment distribution for the entire frame and subtracting the number of redundancies.

For each of the four members of the frame, the loads will be assumed to be uniformly distributed, so that the distribution of bending moment is parabolic. Each parabola will be completely specified if the values of the bending moment at three sections are known. These three sections are chosen most conveniently for the present purpose as the two end sections and the central section in each member. It follows that the bending moment distribution for the entire frame will be specified completely by the values of the bending moments at the nine cross-sections numbered from 1 to 9 in Fig. 4. This frame has three redundancies, and so there must be six independent equations of equilibrium.

It follows that there must be six independent partial collapse mechanisms. These mechanisms are illustrated in Fig. 5. It will be seen that the mechanisms of Figs. 5(*a*), (*b*), (*c*) and (*d*) are merely simple beam failure mechanisms, and Fig. 5(*e*) shows a simple side-sway mechanism. If it were not known that there must be six independent mechanisms, it might be concluded that these five mechanisms constituted the independent partial collapse mechanisms, and thus a calculation of the correct number of independent mechanisms is a vital preliminary operation in the analysis. However, a sixth independent mechanism must be selected, and the most convenient choice is the mechanism shown in Fig.5(*f*). In each figure the rotation of each plastic hinge is given in terms of a single variable θ. There is no need to consider the signs of the plastic hinge rotations, since the virtual work absorbed in a plastic hinge is always positive. However, for convenience in the later stages of the calculations when the solution is checked by statics, the signs of the plastic hinge rotations are also given, the sign convention being that a hinge rotation is positive if the joint is opening when viewed from within the portal.

In the simple beam failure mechanisms of Figs. 5, (*a*), (*b*), (*c*) and (*d*), the plastic hinges within the spans are all shown as occurring at mid-span. However, the loads on these spans are all assumed to be uniformly distributed in the first instance, so that these plastic hinges might occur anywhere within the spans. This is because a plastic hinge within a span must occur at a position of maximum bending moment, and the positions at which the maximum bending moments occur are not known until a later stage in the analysis. However, in the preliminary calculations it is convenient to take these plastic hinges as occurring in mid-span.

Now consider the mechanism of Fig. 5(*a*). For the hinge rotations shown, the plastic hinge at mid-span moves through a distance 60ft. The average displacement of the uniformly distributed load of 0·94 tons is therefore 30ft, so that the virtual work done by this load, taking into account the load factor of 1·4, is $0·94 \cdot 1·4 \cdot 30$ tons-ft. The total plastic hinge rotation involved in the mechanism is 4θ, so that the virtual work absorbed in the plastic hinges is $4\theta M_p$. Applying the principle of virtual work, it is found that

$$4\theta M_p=0·94 \cdot 1·4 \cdot 3\theta=3·95\theta$$
$$M_p=0·99 \text{ tons-ft} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

The virtual work equation for the mechanism of Fig. 5(*b*) is precisely the same as equation (7). Corresponding virtual work equations may be written down at once for the mechanisms of Figs. 5(*c*) and 5(*d*). These equations are :—

Fig. 5(*c*)—

$$4\theta M_p = 1\cdot4[2\cdot61 \,.\, 4\cdot5\theta - 0\cdot76 \,.\, 4\cdot87\theta] = 11\cdot3\theta$$
$$M_p = 2\cdot83 \text{ tons-ft} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Fig. 5(*d*)—

$$4\theta M_p = 1\cdot4[2\cdot61 \,.\, 4\cdot5\theta - 1\cdot52 \,.\, 4\cdot87\theta] = 6\cdot08\theta$$
$$M_p = 1\cdot52 \text{ tons-ft} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

The geometry of the sidesway mechanism of Fig. 5(*e*) is also simple. Each side load of 0·94 tons moves through an average distance of 6θft, and the entire roof moves laterally through a distance 12θft. The virtual work equation is

$$4\theta M_p = 1\cdot4[2\,.\,0\cdot94\,.\,6\theta + 0\cdot76 \sin 22\tfrac{1}{2}^\circ\,.\,12\theta] = 20\cdot7\theta$$
$$M_p = 5\cdot18 \text{ tons-ft} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The geometry of the mechanism of Fig. 5(*f*) is a little more complicated. If the hinge at joint 3 rotated through an angle $-\theta$ while the joint 5 remained rigid, joint 7 would move downwards through a distance 36θft. Since there can be no downwards motion of joint 7 for a small displacement of the mechanism, it follows that the hinge at joint 5 must rotate

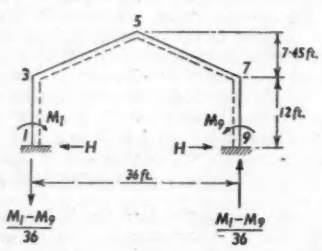

Fig. 7

through an angle 36θ/18=2θ so as to reduce the vertical displacement of joint 7 to zero. This hinge rotation causes a horizontal displacement of joint 7 through a distance 2θ . 7·45=14·9θft, so that the rotation of the hinge at joint 9 is 14·9θ/12=1·24θ. The hinge rotation at joint 7 is then seen to be $-2\cdot24\theta$, and it is found that the centre of the member 57 moves 11·2θft to the right and 9θft downwards. The virtual work equation for this mechanism may now be written down as follows:

$$6\cdot48\theta M_p = 1\cdot4[2\,.\,2\cdot61\,.\,9\theta - 0\cdot76\,.\,9\cdot74\theta + 1\cdot52 \sin 22\tfrac{1}{2}^\circ\,.\,11\cdot2\theta - 1\cdot52\cos 22\tfrac{1}{2}^\circ\,.\,9\theta + 0\cdot94\,.\,7\cdot45\theta]$$
$$= 56\cdot6\theta$$
$$M_p = 8\cdot73 \text{ tons-ft} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Among the six independent partial collapse mechanisms, the highest values of M_p are thus 5·18 tons-ft, and 8·73 tons-ft for the mechanisms of Figs. 5(*e*) and 5(*f*), respectively. The next step is thus to investigate the combination of these two mechanisms. It is seen that if the mechanism of Fig. 5(*e*) is superposed on the mechanism of Fig. 5(*f*), the rotation of the hinge at joint 3 is cancelled, so that the resulting mechanism is as shown in Fig. 6. The virtual work equation for this mechanism is obtained by adding equations (10) and (11), and subtracting $2\theta M_p$ from the resulting virtual work absorbed in the plastic hinges, since a term θM_p was included in each of these equations for the plastic hinge at joint 3. The virtual work equation is thus :

$$(4 + 6\cdot48 - 2)\theta M_p = 20\cdot7\theta + 56\cdot6\theta$$
$$8\cdot48\theta M_p = 77\cdot3\theta$$
$$M_p = 9\cdot12 \text{ tons-ft} \quad . \quad (12)$$

The highest value of M_p obtained from the other four independent mechanisms of Figs. 5(*a*), (*b*), (*c*) and (*d*) was 2·83 tons-ft for the mechanism of Fig. 5(*c*), and it is readily seen that there is no possible combination of these mechanisms with the mechanism of Fig. 6 which will result in a further increase in the value of M_p. It is therefore concluded that the mechanism of Fig. 6 is the actual collapse mechanism, subject to the proviso that no consideration has yet been given to the possibility of the occurrence of plastic hinges at positions other than those numbered from 1 to 9 in Fig. 4. When this solution is checked by statistics it will, in fact, be found that the plastic hinge shown at the apex of the roof in Fig. 6 should be located somewhat to the left of the apex.

Check by Statics.—The solution can be checked by constructing a bending moment diagram for the frame. If the fully plastic moment is not exceeded at any cross-section, the solution is correct. The actual bending moment at a cross-section may be regarded as the sum of the "free bending moment," produced in the frame by the applied loads when a cut has been made at some cross-section so as to render the frame statically determinate, and the "redundant bending moment" produced in the frame by the three redundancies. For convenience, the form of the redundant bending moment diagram will be considered first.

The three redundancies may be taken as the bending moments, M_1 and M_9, at the feet of the vertical members, and the horizontal thrust H, as in Fig. 7. With no external loads acting on the structure, the vertical reactions at the feet of the vertical members would be equal and opposite, and of magnitude $(M_1 - M_9)/36$ as shown in the figure. In drawing the bending moment diagrams, the sign convention will be that a positive bending moment will cause a member to sag inwards, and thus to produce tension in the flange of the member which is adjacent to the dotted line in Fig. 7. With the redundancies as shown in this figure, the redundant bending moment diagram is thus of the form indicated in Fig. 8, in which the members of the frame have been redrawn to a horizontal base, and positive bending moments are plotted as ordinates below this base. In Fig. 8 the dotted line indicates the form of the redundant bending moment diagram for the case in which H is zero, and the full line indicates the effect of superposing the bending moment diagram for the case in which H acts alone.

The free bending moment diagram refers to the bending moments produced in the frame by the applied loads when a cut is made at any arbitrary cross-section. The most convenient choice of cross-section for this purpose is the roof apex. Fig. 9 shows the free bending moment diagram, consisting of three parabolas, which is obtained in this way, the loads having been multiplied by the load factor of 1·4.

The collapse mechanism of Fig. 6 has four plastic hinges at the cross-sections 1, 5, 7 and 9, so that at these cross-sections the bending moment has its fully plastic value, which was found to be

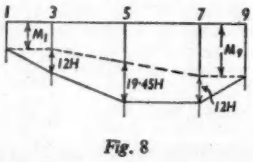

Fig. 8

9·1 tons-ft. To check the solution, it must be verified that a diagram of actual bending moments can be constructed in which the bending moment has the value 9·1 tons-ft at these four cross-sections, and does not exceed this value at any other cross-section in the frame. Now the actual bending moment is equal to the sum of the free and redundant bending moments, so that if a redundant bending moment diagram is drawn in Fig. 9 with the signs of the bending moments changed, the actual bending moment will be represented by the difference in ordinate between this diagram and the free bending moment diagram. The appropriate diagram is shown in Fig. 9 as *ABCDE*.

The construction for this diagram is to lay off from the free bending moment diagram the calculated fully plastic moment of 9·1 tons-ft, with appropriate sign, at the four cross-sections 1, 5, 7 and 9. This gives the four points *A*, *C*, *D* and *E* on the redundant bending moment diagram. Referring to Fig. 8, it is seen that the point *B* may then be plotted by making the slope of *AB* equal in magnitude to the slope of *DE*, but of opposite sign. A check can then be made by observing that the vertical intercept between *C* and the dotted line in Fig. 9 is 19·45 *H*, whereas the corresponding intercept at *D* is 12 *H*. These intercepts both correspond to a value of H of 0·05 tons, thus checking the solution. However, it will be seen that although the bending moment at the cross-section 3 is less than the calculated fully plastic moment of 9·1 tons-ft. a higher value of the bending moment occurs at a distance of 2·8ft along the left-hand rafter member from the apex joint, this value being 9·6 tons-ft. This does not imply an error in the virtual work calculations, for in those calculations the choice of plastic hinge positions was restricted to the ends and centres of the members. The calculation of the required fully plastic moment could be refined by carrying out a fresh virtual work calculation in which the plastic hinge at the apex joint 5 was moved to the new position 2·8ft along the left-hand rafter member. However, it is unnecessary to perform this calculation, for it will be seen that the design is, in fact, not governed by this loading case but by the dead and superimposed loading case. It is therefore noted that a value of M_p between 9·1 and 9·6 tons-ft would be adequate for dead, superimposed and wind loads in conjunction.

Design for Dead and Superimposed Loads.—The design for dead and superimposed loads to a load factor of 1·75 will now be considered. The relevant working loads are merely loads of 2·61 tons uniformly distributed over the two rafters, as shown in Fig. 10(*a*). Since this loading

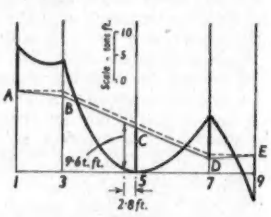

Fig. 9

is symmetrical, the bending moment distribution for the frame is also symmetrical, and so only four bending moments are needed to specify the bending moment distribution. These may be taken as the bending moments at the cross-sections 1, 3, 4 and 5 in Fig. 10(*a*). Due to symmetry, the frame has only two redundancies, for the bending moments at the cross-sections 1 and 9 are equal. The bending moment at cross-section 1 and the horizontal thrust can thus be regarded as the two redundancies. It follows that there are only two equations of equilibrium, and therefore two independent mechanisms. Both of these mechanisms must be symmetrical.

The two independent mechanisms are illustrated in Figs. 10(*b*) and 10(*c*). Fig. 10(*b*) merely represents failure of the two rafters as beams, and the equation of virtual work is

$$8\theta M_p = 2\,.\,2\cdot61\,.\,1\cdot75\,.\,4\cdot5\theta = 41\cdot1\theta$$
$$M_p = 5\cdot14 \text{ tons-ft.} \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

In the mechanism of Fig. 10(*c*) the hinge rotation θ at cross-section 1 would produce a horizontal movement of 19·45θ at the roof apex if there were no hinge rotation at cross-section 3. The hinge rotation at cross-section 3 must

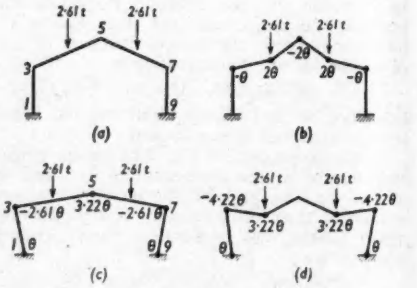

Fig. 10

therefore be $-19\cdot45\theta/7\cdot45 = -2\cdot61\theta$ in order that there should be no horizontal movement at the apex. The downwards vertical displacement at the apex is thus $18\,.\,1\cdot61\theta = 29\cdot0\theta$ft. The virtual work equation is :—

$$10\cdot44\theta M_p = 2\,.\,2\cdot61\,.\,1\cdot75\,.\,14\cdot5\theta = 132\cdot5\theta$$
$$M_p = 12\cdot7 \text{ tons-ft} \quad . \quad . \quad . \quad . \quad . \quad (14)$$

It will be noted that this value of M_p exceeds the value found for the case in which the wind

loads act in conjunction with the dead and superimposed loads. It follows that the design must be governed by the present case in which only the dead and superimposed loads are acting.

Considering now the combination of the independent mechanisms, it will be seen that cancellation of the plastic hinge rotation at the roof apex can be achieved by superposing the mechanism of Fig. 10(*b*), with all the hinge rotations and displacements increased by a factor of $3 \cdot 22/2 = 1 \cdot 61$, on the mechanism of Fig. 10(*c*). The mechanism thus obtained is illustrated in Fig. 10(*d*). The virtual work equation for this mechanism is obtained by adding equation (13), multiplied by 1·61, to equation (14), and subtracting $6 \cdot 440 M_p$ from the resulting virtual work absorbed in the plastic hinges, since a plastic hinge rotation of 3·220 in each of the mechanisms at the roof apex has been cancelled. The resulting equation is :—

$$(8 \cdot 1 \cdot 61 + 10 \cdot 44 - 6 \cdot 44\theta) M_p = 41 \cdot 1 \cdot 1 \cdot 61\theta + 132 \cdot 5\theta$$

$$16 \cdot 88\theta M_p = 198 \cdot 7\theta$$

$$M_p = 11 \cdot 8 \text{ tons-ft} \quad . \quad (15)$$

The highest value of M_p obtained from these mechanisms is thus 12·7 tons-ft for the mechanism of Fig. 10(*c*). This is therefore the actual collapse mechanism, subject to possible alterations due to the occurrence of plastic hinges within the spans of the members rather than at

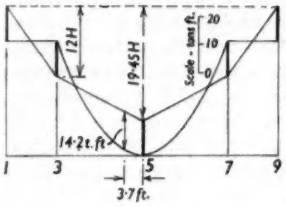

Fig. 11

the joints. A statical check will reveal, in fact, that the plastic hinge at the roof apex should be replaced by one plastic hinge in each rafter member.

Check by Statics.—The free bending moment diagram for the frame, cut at the roof apex, when subjected to the factored loads, is shown in Fig. 11, together with the redundant bending moment diagram. This latter diagram is constructed by setting off the calculated fully plastic moment of 12·7 tons-ft from the free bending moment diagram at the cross-sections 1, 3, 5, 7 and 9. The value of the horizontal thrust can be calculated from the intercepts between the redundant bending moment line and the dotted line in Fig. 11 at both the cross-sections 3 and 5. The value obtained in each case is 2·1 tons, thus checking the virtual work calculation. It will be seen that the greatest bending moment which occurs with this bending moment distribution is 14·2 tons-ft at a distance of 3·7ft from the roof apex. Thus in the correct collapse mechanism there should be plastic hinges in each rafter at a distance of about 3·7ft from the roof apex in place of the single plastic hinge shown at the apex in Fig. 10(*c*). A fresh calculation for these new plastic hinge positions is readily made, either by virtual work or by adjusting the redundant bending moment line on the bending moment diagram, and the resulting value of M_p is found to be 13·2 tons-ft. A final refinement is to take account of the fact that the loads are not, in fact, uniformly distributed over the rafters, but are carried by five uniformly spaced purlins, as shown in Fig. 4. The plastic hinges in the rafters will be located beneath the purlins which are adjacent to the roof apex, and the corresponding value of M_p is found to be 13·0 tons-ft or 156 tons-in.

A choice of section can now be made. The fully plastic moment for a rolled steel joist is known to exceed the moment at which the yield stress is just reached in the outermost fibres by a factor termed the shape factor, which is about 1·15 for most sections.[4] Taking a yield stress of 15·25 tons/in², the fully plastic moment M_p is thus :—

$$M_p = 1 \cdot 15 \cdot 15 \cdot 25 \cdot Z = 17 \cdot 5Z \text{ tons-in}$$

where Zin² is the section modulus. The required value of Z in the present case is :—

$$Z = 156/17 \cdot 5 = 8 \cdot 91 \text{in}^2$$

The nearest available British Standard beam section is a 7×4×16 lb, with a section modulus of 11·29in². This is therefore the required section. From the point of view of stability, the purlins and sheeting rails, together with some cross-bracing, would provide adequate stiffening for this section over the given spans.

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(To be continued)

A West Bengal Bicycle Factory

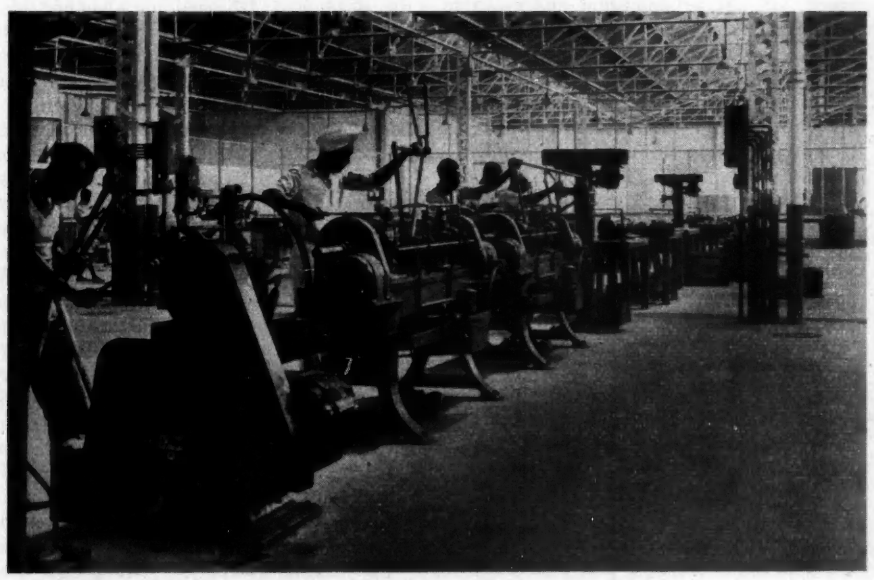
(By Our Indian Correspondent)

THE first modern bicycle factory to be built in India was established near Bombay by the Hind Cycles, Ltd., in 1939. The company made almost every part except free-wheels, chains, spokes and nipples, But owing to various reasons such as the shortage of steel, foreign steel tubes and rim materials, the production, even in 1951, just managed to reach about 84,000, only 42 per cent of its productive capacity of 200,000. There are other manufacturing units in the country but they are small in size and, according to the Ministry of Commerce and Industry, the total production in 1951 was 114,275. The Planning Commission's target for 1955–56 is 500,000, to be achieved with the establishment of at least four more factories, but despite the nucleus of a small cottage industry producing such parts and accessories as mudguards, bottom axles, hub axles, bottom cones, bottom cups, carriers, pumps and saddles, it is not really expected that much headway can be made without the active participation of foreign capital and organisation. A start appears to have been made with the opening on June 21, 1952, of a new factory at Kanyapur, by the Sen-Raleigh Industries of India, Ltd.

Kanyapur is about 3½ miles from Asansol West Bengal, and lies in the Damodar Valley belt, drawing its power supply from the Damodar Valley grid. The factory has been built in association with the Raleigh Industries of Nottingham, who are providing technical assistance, particularly in the planning of the factory, the procurement of scarce plant and raw materials and the training of Indian personnel. The company was registered in June, 1949, as a public limited company with an authorised capital of Rs.1 crore (£750,000), 93 per cent of the shares being held by Indian nationals. The company have also entered into technical agreements with Union Sils Van de Loo and Co., and Wittkopp and Co., of Germany, for the manufacture of cycle components in India. Its initial capacity is in the region of 100,000 units per year, gradually rising to 200,000, which is the ultimate installed capacity. It occupies a covered area of nearly three acres and a new township is being planned around it with its own water supply, electric sub-station and sanitary facilities. Of the plant already installed the shot-blasting chamber is unique in India ; in addition, there is a fully equipped bonderising section and an enamelling department. Production of frames, forks, mudguards and backstays has already been started. A view of the frame and fork shop is reproduced herewith. Delivery of complete machines is expected to begin by the middle of next year.

A Symposium on Cement

AN international symposium on the chemistry of cement is to be held in London from September 15th to 20th. It has been organised by the Cement and Concrete Association, 52, Grosvenor Gardens, London, S.W.1, and will be held at the Royal Institution and the Royal Society of Arts, under the presidency of Sir Ben Lockspeiser. The papers to be discussed are on subjects such as the early history of Portland cement in England ; detailed chemical papers, entitled "The Tricalcium Silicate Phase" and "Chemical Aspects of the Durability of Cement Products," to give only two examples, from twelve titles grouped under the general headings of the constitution, and setting and hardening of Portland cement ; five papers each devoted to a different sort of special cement ; and four papers on the application of research, which are entitled "Thermodynamics of the Cement Kiln," "The Influence of the Fineness of Cement Raw Mixes on Their Burning Characteristics," "Effects on Concrete Technology of Modern Developments in Construction," and "Development of Cements for Special Uses." The closing address is entitled "Cement Research and the Future." The authors of the various papers represent the cement industry of various European countries and of the United States and Canada. The symposium also includes various social functions, such as visits to works within the neighbourhood of the London area.



Frame and Fork Shop at Sen-Raleigh Factory, Kanyapur

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THE S.B.A.C. DISPLAY

It is an illustration of the pace of technical advance in aeronautics that each year since the war the S.B.A.C. Show at Farnborough has revealed, merely twelve months after its immediate forerunner, some very significant changes. Since the war, in fact, our age has witnessed a really astonishing evolution in flight. At each Show some new prototype faster, larger, or of greater range than any aircraft built before has been seen in flight. These craft have been built from data tediously and laboriously gathered from the very boundaries of aeronautical knowledge, and after the prototypes have flown they have themselves contributed data applicable to their own improvement. Naturally one thinks first of the rate at which the maximum speed of aircraft has been pushed up towards and even beyond that of sound. There the problems of design of high-speed aircraft seem to have proved less formidable than it was thought, some years ago, they might be. But other prototype aircraft which have joined in these displays have been questing after advances less flamboyant than those in speed, yet just as significant and valuable. One craft, for instance, in a single great stride, gave engineers a better appreciation as to how large an aircraft could be made. In others, hidden from the spectator, there are more secret improvements which, in fact, are just as significant as the very obvious increases of speed. The power assistance provided, to varying degrees, in control systems is, for instance, essential for the operation of certain aircraft which, it is thought at the moment, could not be adequately flown without it.

Undoubtedly, the basic reason for the rapid recent advances in aircraft design lies in the development of the gas turbine power unit. The objectives now confidently sought in high-speed aircraft are made and have been made attainable solely because the gas turbine engine can provide, in conjunction with low weight and small frontal area, very great thrusts. Moreover, the specific fuel consumption has been, and continues to be, reduced compared with that obtained from earlier production engines. But as speeds of flight were pressed up beyond that attained by an immediate post-war aircraft such as the "Meteor," it became abundantly clear that, at such speeds, neither in performance, nor in calculation, could air continue to be regarded as an incompressible fluid. The changes in air flow, as problems of compressibility asserted themselves, were expected to effect fundamental changes in aircraft design. Just how aircraft profiles have been transformed has been made more clearly evident by succeeding displays at Farnborough. Emphasis soon began to be placed upon the advantages of sweep-back in delaying the compressibility effects due to wing curvature at aircraft speeds still in the high sub-sonic range. Similar arguments led also to the adoption of very thin wings relative to their chord. Such wings not only reduce the still great increases in drag which occur with conventional skin wings, but the control and stability in the pitching plane were claimed also to be superior to straight wings. But the nature of this wing introduced serious structural problems, amongst which stood out the increased torsional requirements which had to be met, and the wing also exhibited aerodynamic disadvantages at landing speeds. Not only was the wing important, however, in such considerations, but the fuselage as well, and particularly the method of joining wings to fuselage and of the kind of air intake adopted. The optimum fuselage shape appears to be a long but slim structure with the smallest possible frontal area. Such considerations have reacted upon the design of the gas turbine itself, and the higher thrust per unit of frontal area, characteristic of the axial-flow engine, has been a contributory reason for the adoption of that engine in most of the aircraft now in production. But this upheaval in aircraft design was still only in its infancy when the delta configuration began to be tried. Since the first arrival of a delta-wing aircraft at Farnborough, delta configurations have been under extensive development in this country. One such craft is now in quantity production and a bomber version has been ordered off the drawing board in "appreciable numbers." Much has been claimed already for this design. It attains the higher torsional stiffness requirements by occupying the vacant area behind the trailing edge of the swept wing, and it has several other structural advantages arising from the single envelope which the wing and body form. It is significant that, because of the low wing loading and of other inherent aerodynamic properties, the bomber version has no tail plane and no flaps or other high-lift devices. Such are the flying characteristics claimed for the delta-wing aircraft now in production that the makers believe the machine to be more manœuvrable and docile at lower speeds than any fighter since the biplane era !

At this year's display, then, one significant advance which might be recorded is the emergence of the delta configuration as one not only suited for large military aircraft, cruising near the speed of sound over long distances, but for very large civil aircraft as well. It is also the first display where supersonic demonstrations have been made, and it is a display which was, at the time of writing, on the verge of revealing a development in boundary layer control as outstanding as the delta itself. Nowhere is it stated, however, that these aircraft can maintain flight at sonic speeds, and it is improbable that they have the power to do so. Truly supersonic aircraft are still not with us, but it cannot now be very long before such an aircraft will make its debut at Farnborough. Much is already known of the more tangible aerodynamic and structural problems which the design of such aircraft will present. The attainment of supersonic cruising speeds will mostly depend on power units geometrically suited for the enormous thrusts required, and even now, under development. Curiously enough, at these greater speeds the straight wing may once more gain favour, for above Mach numbers in the region of 1·4 the drag characteristics promise to assume about the same values as those of the swept wing. What shape, therefore, the supersonic machine will assume has yet to be seen. Even the biplane may be reborn ! Up to Mach numbers of around 4, the purely physical problems of supersonic flight may well be behind us sooner than we expect, for once the sonic "barrier" is passed drag coefficients fall. But beyond flight at that Mach number there can be discerned a new problem. The skin temperatures generated in flight at speeds above Mach 4 may exceed those which present-day metals can stand. That problem may prove to be one, therefore, for metallurgists, rather than aerodynamists.

THE BRITISH CONTRIBUTION TO STRUCTURAL ENGINEERING

The occasion of the fourth congress of the International Association for Bridge and Structural Engineering, which has been in progress in Cambridge and London for the past fortnight, has been an important one for the structural engineer. A large number of papers covering a considerable diversity of subject matter was presented during the first week, embodying the results and conclusions of much of the most advanced work in structural engineering which has been in progress in recent years. As would be expected, no startling new discoveries have been divulged, but rather more complete statements of the progress made in evolving

new design methods or structural theories over a long period. There were contributions from most Western European countries and from India and the United States, covering both practical problems of structural erection, and theoretical researches and analyses, which, however, all had a direct bearing on structural design. It is evident from the papers of the congress that progress in structural engineering is at present being brought about by two mutually dependent factors. The development of comparatively new materials and techniques, such as the use of light alloys and of welding, for example, brings new methods which may modify indirectly other sorts of construction. The basic approach to structural analysis and design is also changing ; new concepts in the basic theory of structures, as may well be appreciated, may cause profound changes in design. An example of this aspect is the examination of the idea of the factor of safety, based upon working stresses, and its gradual replacement to-day by the load factor, based upon the failing load of a structure. This subject is examined by various authors of the papers and general reports in the Association's preliminary volume for the congress.

Many of the papers read by the British authors deal with topics which will doubtless be familiar to readers of this journal, and from one point of view it is probably the papers from other countries which will be of the greatest value here, as they illustrate the lines along which structural engineers abroad are thinking, and the results they have achieved. However, the British contribution to the technical work of the congress is a prominent and meritorious one. Doubtless the fact that the congress took place in Britain acted as a stimulus to prospective authors, but the diversity and originality of the British papers is particularly satisfying when it is recalled that structural engineering is curtailed at present by governmental restrictions on expenditure. In spite of the lack of opportunity for large-scale works, those in Great Britain engaged in research, design and the erection of structures, made noteworthy contributions to the congress. The important research in progress under the direction of Professor Baker at Cambridge on the plastic analysis of steel structures was exemplified by four papers, one of which we reproduce elsewhere in this issue. Also, wind tunnel tests of the proposed Severn suspension bridge, and their theoretical background, were described, and there were papers on some aspects of the analysis of beams—all in the first two sections of the proceedings of the congress which dealt with general questions of theory and calculation. Modern welding practice was exemplified by the description of large welded girders erected during the course of recent steelworks construction, and erection methods for large steel bridges were commented upon. One problem which has been unique to this country—the analysis of the Dome of Discovery—was also described ; it provided an interesting example of the solution of a structure with 318 degrees of statical indeterminacy. In the field of concrete technology there were also distinguished contributions by British authors, covering such subjects as the design of mixes, combined bending and torsion, and the use of high-strength steel in reinforced and prestressed concrete.

As may well be appreciated, all of these contributions reflect great credit on British engineers. The congress was very successful, and structural engineers from many countries were entertained here and exchanged technical ideas with each other, outlining their own advances and hearing of British ones. There was, perhaps, only one thing lacking. There were few structures in course of erection, or recently built, which could be shown as examples of the structural engineers' skill. It is unlikely that the progress recorded in papers from overseas will be neglected by structural engineers here, as their own papers indicate that every opportunity for improvement is taken. There are, however, too few works in progress to expect that the highest level of technical achievement can be maintained. In the words of Mr. E. S. Andrews, at the congress's banquet, what the structural engineer needs is " more liberty and less licence." He has demonstrated how well he is able to design and build structures, but he needs more opportunity for exercising this skill.

Literature

Introduction to Electronic Circuits. By R. FEINBERG. London : Longmans, Green and Co., Ltd., 6–7, Clifford Street, W.1. Price 18s.

THERE is little doubt that Johnstone Stoney, in 1891, first used the word " electron " to describe an elementary electrical particle. There is far less certainty in the origin of the word "electronic" and in its precise meaning. It is claimed to have American origin, and is defined in the American Standard Definitions of Electrical Terms as " that branch of science and technology which relates to conduction of electricity through gases or in vacuo." So general is this definition that any book on electronics or electronic circuits must be examined to see what is intended to be covered. Dr. Feinberg, in his " Introduction to Electronic Circuits " considers the external effects of electronic devices arising from the peculiarities of their voltage-current characteristic and lists them as : " rectification, control of current, amplification, frequency multiplication and intermodulation, negative-resistance performance and electronic-switch action."

The first chapter on vacuum valves starts with a description of the diode, its characteristic and its application to rectification. There follows the triode and its application to amplification. Many readers will be surprised to see the anode characteristic of the triode with anode current as abscissa and anode voltage as ordinate. This is the reverse of normal practice, and at first glance the characteristic looks like that of a pentode. The valve factors are defined, but the important and simple derivation of their interrelation is omitted. The equation $\mu = g_m r_a$ is simply stated as being " in accordance with the mathematical theory of a surface in space."

The second chapter on vacuum valves deals with the tetrode and pentode. A serious omission is the absence of any reference to the reduction in inter-electrode capacitance brought about by the additional grids. The author has departed from his declared purpose in this chapter by considering the internal effects of two electronic devices : the basic magnetron and the cathode-ray tube. The inclusion of the latter is well justified owing to its important and widespread use in the investigation of circuit performance. The former might well have been omitted as coming in the realm of u.h.f. techniques which are outside the scope of the book.

In the next chapter on fundamentals of alternating current amplification, the basic amplifier circuit is first of all analysed. There is considerable repetition in the treatment. First the equations derived in the first chapter are reproduced for alternating current instead of direct current with a corresponding change in nomenclature. Then the analysis with a general load " Z " repeats that with a resistive load " R." The multiplicity of equations produced by this treatment does not make for clarity. There is further complication by the introduction of both voltage amplification of a valve and voltage amplification of an amplifier, with mathematical expressions derived for both. Some minor errors have occurred in the analysis. The constant voltage equivalent circuit is deduced but no reference is made to the constant current equivalent circuit. Power amplifiers are then considered but the optimum power calculations cover only the case of constant excitation with no mention of distortion. After an explanation of the classification of valve operation the misleading statement is made that " a.c. amplifiers are normally operated in class A1."

The second half of the chapter is devoted to " feedback " starting with the Miller effect. The expression for input admittance is stated with no clue as to its derivation which involves the solution of two simultaneous equations after application of Kirchoff's Laws. Deductions from this general expression, showing the effect of various types of load are, however, clearly presented with the use of vector diagrams. The cathode follower is then analysed and finally there is the mathematical analysis of an amplifier with voltage negative feedback.

The fundamental theory behind rectification, frequency changing and amplitude modulation is covered in a chapter on the non-linearity effects of vacuum valve characteristics. This gives a mathematical analysis by applying Taylor's Theorem for a diode, triode and hexode in turn. Circuits for selecting the particular non-linearity effect desired are shown but no practical circuit details are given.

The next chapter contains the theoretical treatment of sinusoidal oscillators. The usual types of oscillators are considered and examples are given of the very theoretical derivation of maintenance conditions. Important omissions are the transitron and the Wien Bridge resistance-capacitance oscillators. There is no mention of methods of feed, frequency stability and the use of crystals.

The chapter on relaxation oscillators contains a good treatment of a sawtooth-voltage generator and a multivibrator. Voltage and current waveform diagrams are clearly shown and the mathematical analysis is straightforward. There is a very minor error in equation (VI. 4) where Δv_{gT} should be written instead of v_{gT}.

The last part of the book deals with the separate subject of conduction through gases. After a physical description of the behaviour of the gas-filled diode and triode there follows an explanation and analysis of rectifiers and inverters. The mathematical treatment is simplified by recourse to equivalent functional diagrams and the use of approximations. Certain practical matters have been included in this chapter such as the care

required when using mercury-vapour valves, although the need for pre-heating cathodes of valves filled with inert gas is not mentioned. It is noted that no reference is made in the text of the book to the word " thyratron," originally a proprietary word, but now included in the British Standard Glossary to mean a gas-filled valve with a control electrode. Cold cathode valves, photo valves and mercury-pool valves are considered briefly in the final chapter.

The author has adopted throughout a somewhat unusual treatment whereby each particular subject rigorously follows a formal pattern. The technique is described in the preface as the following sequence : " (1) description of the physical structure of the object, (2) explanation of the mechanism of its action, (3) translation of the mechanism of action into mathematical terms with, where necessary, a statement of the assumptions made to obtain a simplified mathematical formulation, (4) examination of what can be deduced from the assumptions as a first approximation, (5) directions for experiment, (6) numerical problems with a practical bearing, (7) some literature for any further reading." The descriptions and explanations are succinct. The mathematical analysis is lucid. There are cases, some of which have been mentioned, of expressions being quoted which should have been derived. The directions for experiment form a valuable feature and serve to augment the somewhat sparse descriptive treatment and supply a practical aspect. The inclusion of numerical problems, with answers, is another good point. The selection of literature is well chosen but it is felt that in many cases there may be a difficult gap for the reader to bridge between the fairly elementary text of the book and the more advanced treatments that will be found in some of the articles, for example : the *Journal of the Institution of Electrical Engineers* and the *Proceedings of the Institute of Radio Engineers*.

The rationalised M.K.S. system of units is used and the British Standard Glossaries are followed. The author has adopted a logical and consistent system of symbols which overcomes the difficulties normally experienced in expressing the various voltage and current relations associated with valve circuits. A good system is also followed in showing current direction and voltage drop in the circuit diagrams.

In spite of the criticisms directed against the earlier part, the book is strongly recommended as a valuable additional text book for the electronics student and as a reference book for those interested in the theory of circuits rather than their practical features. The latter part of the book contains good treatments on subjects not normally found in electronics text books.

Practical Mathematics. Volume I. By Louis Toft and A. D. D. McKay. Third edition. London : Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 20s.

It is twenty years since the first edition of this book was issued. Published in the Pitman Engineering Degree Series, its intention was then, and is now, to cover the mathematics required for the London University Degree in Engineering. This third edition is being produced in two volumes. Volume I covers the subject matter of Part I of the London B.Sc. examination in the subject. For this purpose a new chapter on statistics has been included and some minor additions made to the treatment given in earlier editions.

So well known to teachers and students alike is this standard textbook that a full account of its contents is not required. Moreover, the book is well described by its title of " Practical Mathematics." In addition to meeting the exact needs of the degree student, it provides a text book of the mathematics required by the engineer and technologist. This is largely achieved by the careful selection of the contents, the clear and readable style adopted and the interlarding of numerous worked examples with a practical bias. There is, however, no loss in the essential mathematical rigour and such analysis as is required by the engineer, as opposed to the mathematician, is included. This is perhaps best illustrated by a brief examination of the logical sequence that has been employed.

The book starts with a consideration of limits and convergence, and an examination of important series leading on to differentiation and then integration. Applications then follow, including a discourse on conic sections, graphs and other curves important in engineering. First order and second order differential equations are then dealt with, the latter by the use of operators. After the penultimate chapter on Statistics and Correlation there is in the final chapter a brief mention of vectors with application to planar motion.

At the end of each chapter a liberal supply of examples, many taken from London University examination papers, is provided. Answers to all the examples are given at the end of the book, followed by an index. The book is very well produced ; the diagrams are good ; the equations are clearly set out. For the benefit of those familiar with the second edition it should be mentioned that two chapters, Determinants and Spherical Trigonometry, have been omitted from Volume I of this edition. They will presumably be included in Volume II, now in preparation. The advent of the second volume of this valuable book is awaited with interest.

SHORT NOTICES

Foundations of Electrical Engineering, Volume I. By Professor H. Cotton, D.Sc., M.I.E.E., and E. W. Golding, M.Sc.Tech., M.I.E.E. London : Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, W.C.2. Price 20s.—The authors of this book have collaborated in an attempt to meet the particular needs of National Certificate candidates in their studies of the theory of the electric circuit and of the principles of electrical machines. To do justice to the wide field covered by this subject, the authors have arranged the material in two volumes, of which the first gives a full treatment of elementary principles and thus provides a sound basis for further study. A list of some of the chapter headings indicates the scope of the work : " Units," " The Electric Circuit," " Resistance and Temperature Rise," " Conductors and Insulators," " Electrostatics," " Electromagnetism." From these first principles the book proceeds to a study of the magnetisation of iron and steel and, thence, of direct current machines. Direct current generators and motors are studied in a general way in separate chapters ; and in a later part of the book these topics are given more advanced treatment in chapters dealing with the characteristics of direct-current generators and motors, and their operation and testing. A similar treatment is accorded to the subject of illumination, elementary principles being presented in Chapter XV and more advanced work in Chapter XXIII. There are a number of worked examples in the text and a collection of problems to be worked by the student is given at the end of the book. A useful innovation is the inclusion, at the end of each chapter, of a number of suggestions for experimental work which should do much to stimulate the students' interest.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

LOCOMOTIVE WHEELS AND ACCELERATION

Sir,—In your issue of August 29th, Mr. E. B. Parker remarks that " it is not clear why your reviewer regards as a ' time-honoured misconception ' the statement that the smaller the wheel the better the rate of acceleration." The possible acceleration of a train on level track is determined by the total moving mass and the propulsive effort developed by the locomotive at the treads of the driving wheels. The propulsive effort is subject to two upper limits, (1) the product of adhesion weight and coefficient of friction, (2) something closely approximating to the nominal tractive effort of the locomotive.

In starting from rest and at low speeds, with conventional locomotives and rails in normal condition, (1) is the lower of the limits and therefore determines the maximum possible acceleration. It is entirely independent of wheel diameter.

If the conditions are such that (2) is the controlling limit, it may be said that, in those circumstances, increase of nominal tractive effort gives greater acceleration. Nominal tractive effort depends on number of cylinders, steam chest pressure, cylinder bore, piston stroke, and driving wheel diameter. None of these has any meaning in this connection without the other four, and so it is irrational to say that smaller wheels give better acceleration. This becomes a statement with a meaning only if accompanied by the provisos that (*a*) number of cylinders, steam chest pressure, cylinder bore, and piston stroke remain unchanged, and (*b*) the nominal tractive effort does not exceed the product of adhesion weight and coefficient of friction.

Even with these provisos all observed—and (*b*) very rarely is—the statement is misleading because the singling-out of wheel diameter from five factors wrongly suggests a unique significance for it. Nevertheless, the statement has so often been made with no qualification whatever that it is now regarded by some as if it were an unquestionable axiom, instead of a misconception resulting from loose thinking. Its popularity has probably been reinforced by the fact (observable without thinking at all) that for any given train acceleration the smaller the driving wheels the higher the rate of change of exhaust beat frequency.

The specific comparison mentioned by Mr. E. B. Parker (page 290) is useless as a demonstration unless it is certain that each engine was being accelerated as fast as possible. Were that done, the 2–6–2T could be expected to produce acceleration about 50 per cent higher than that of its rival (assuming a 150-ton train in each case), because it has 35 per cent advantage in adhesion weight and 10 per cent less total mass to move. Wheel diameter does not enter into the matter at all.

Your Reviewer

Sheffield, August 30th.

" POWER " AND " POWERFUL "

Sir,—The letter from Messrs. Simpson and Browne Roberts, on page 255 of your issue dated August 22nd, together with your reviewer's comments, gives point to the general looseness with which the words " power " and " powerful " are used. Too many people (and even some engineers) say power when in fact they mean torque or straight pull, while others use it when they mean " large and sustained rate of work."

Will you, Sir, use the influence of your paper to insist that writers of articles and correspondents use words which state exactly what they mean in the engineering sense, and so improve the precision of engineers generally ?

Regarding the ex-G.W.R. " Kings," no one

who has travelled behind these locomotives between Paddington and Birmingham with trains of fifteen coaches could doubt their ability both to start a 500-ton train and also to keep it moving at high speed on a road which is by no means easy—especially in view of the standard practice on the old G.W.–G.C. joint section of parking the goods trains on the fast line and diverting the express to the slow line and back again, sometimes at both High Wycombe and Ruislip !

R. E. MORRISON,
M.I.Mech.E.

Walton-on-Thames, August 30th.

CLUTCHES FOR COMMERCIAL VEHICLES

SIR,—I am glad to see in your issue of August 15th that a new Borg and Beck clutch has been introduced for use on commercial motor vehicles. It may be of interest to add that the new feature of this clutch, namely, the leaf spring attachment of the presser plate to the fixed plate, is a long overdue improvement which I devised and embodied into the design of the 14/45 Talbot and the subsequent 90 and 105 models over twenty-five years ago.

GEORGES ROESCH,
M.I.Mech.E., M.S.I.A., M.S.A.E.

London, N.W.11, August 30th.

SCIENCE AND APPLIED RESEARCH

SIR,—What a good summing up of the debate in the Lords you made in your recent leading article entitled " Their Lordships and Science," in saying : " For interesting though each contribution was, little that was fresh was really said." It seemed to me that various speakers wanted something done, but could not say how to do it, and that neither the Government, its servants, nor its committees know how to do what they want to do.

Lord Woolton has asked the President of the Scientific Advisory Council to look into the efficiency of research. Practically speaking, he is doing in a lackadaisical way what you suggested should be done in 1944 ! But the Scientific Advisory Council is almost being asked to " Review what you and your contemporaries are doing, and find yourself guilty." Is that not so ! I do not mean anything sinister. The scientist simply cannot see matters at the industrial level and that is the one that matters ! In my opinion the men to carry out the review called for by Lord Woolton are open-minded men who have had a technical training and then have gone over to the commercial side successfully.

I would like to see an investigation into the results of university research. It seems to me that it should produce the rules by which the inventor and the designer can work ! When it does make inventions they seem to be " scientific instruments " and not " wealth producing tools " ! And it is the new " tools " that we require ! To my mind Lord Kelvin is a case of that. His " scientific instruments " were marvellous, but if he could have invented " tools " Glasgow ought to have been the seat of the telephone industry and also have had a heavy electric industry ! Another thing of which people should be made very much aware is the point you make in " Applied Research " about " it is a tiny nucleus of a staff which seems to be able to keep a whole team going." Are these men being used in the right way ? You cannot have " insight " unless you have gathered all the relevant information—I am pretty sure of that.

After reading the reports of the National Research Development Corporation and the address given by its managing director to the Royal Society of Arts these points seem to call for investigation :—

(1) Is this Corporation going in for the development of " scientific instruments," and not for new " industrial goods " ?

(2) Has it any use for the true technical inventor ? Has it got any understanding of this type of man and how to use his services ?

(3) What is being done for these inventors who have developed their inventions and cannot obtain capital to put them on the market ?

The N.R.D.C. seems to be simply handing over these inventions to existing industry, but as such people as Dr. H. S. Hatfield and the late Professor Sir James B. Henderson, &c., have pointed out, to get a real advance it has to be done in the face of existing industry.

SYMINGTON MACDONALD

Edinburgh, August 29th.

Electronics Symposium and Exhibition

THE electronics symposium and exhibition organised by the Scientific Manufacturers Association of Great Britain, Ltd., was opened on Tuesday, September 2nd, at the Examination Hall, Queen Square, London, W.C.1, and closes to-day, Friday, September 5th. Besides the technical papers comprising the symposium, there is the exhibition, which contains a comprehensive display of British electronic instruments.

On Tuesday, September 2, 1952, G. H. Hickling, B.Sc., A.M.I.E.E. (Sir Howard Grubb, Parsons and Co.), presented a paper on " Electronic Control Systems for Large Astronomical Telescopes." The paper opened with a short introductory discussion of the astronomical factors leading to the requirement of very accurate control of " rate " in the drives for large telescopes. This discussion was followed by a review of the techniques employed up to the present time to achieve this end, culminating in the present-day forms of electronic control. These controls have developed from methods based on the pendulum clock and, later, on tuning forks as the standard of reference ; while to-day the quartz crystal with a frequency stability in the order 1 in 10^8 is the best known and most accurate standard of reference. A modern requirement is the ability to introduce small variations of rate, and to provide for this a recent development has been the application of very stable " R-C tuned " oscillators, either as the actual source of the reference frequency or as the means of introducing frequency variation in a crystal controlled source.

With passing reference also to photo-electric methods of control, the application of these principles to actual telescopes drive systems was illustrated by references to various recent projects including reflectors up to 74in aperture and a " Photographic Zenith Tube " shortly to be installed in this country to provide a new standard of absolute time determination.

On Wednesday morning, September 3rd, " The Development of Resistive Elements and Wave-Guide Attenuators from a Semi-Conducting Ceramic " was discussed by J. M. Herbert, B.Sc., A.R.I.C. (The Plessey Company, Ltd.), who pointed out that in contrast to the majority of semi-conductors the temperature coefficient of resistivity of very pure zinc oxide could be controlled between high positive and negative values. The addition of titanium dioxide makes it possible to achieve this control with commercially available materials, and to control the value of the resistivity. Small resistors up to 10,000 ohms in value and having value tolerances and stability similar to Grade B carbon composition resistors have been made and can be run with surface temperatures up to 200 deg. Cent. It has not been possible to manufacture small sizes because of the difficulty of devising a satisfactory method of making an electrical connection to small pieces. Large resistors for running in series with valve filaments can be made satisfactorily. Elements with very high positive temperature coefficients of resistance can be used as current regulators where the supply voltage is variable. The control is not as good as that given by an iron-wire-in-hydrogen Barreter, but might have practical uses. The material has proved very satisfactory in the manufacture of dummy loads to fit in metal wave guides as it is unaffected by rapid temperature changes and combines high attenuation with a good match. It is also being developed in the form of attenuator vanes.

The same morning D. L. Johnston, B.Sc., and D. W. Hobbs (Elliott Brothers (London), Ltd.) gave a paper dealing with " Electronics in Strain Measurement." It included the description, performance and uses of various electronic instruments which have been designed to meet the growing demands of research and industry in these fields, such as multi-channel strain display equipment, high-speed self-balancing strain bridges, load indicators, load cells and torque meters.

On Wednesday afternoon G. Mole, Ph.D., F.Inst.P. (The Electrical Research Association), described " Electronic Instruments Developed by E.R.A. for Research in the Electrical Industry." Some of these instruments have to satisfy special requirements to render them suitable for the testing of heavy-power electrical equipment. Their functions include the control of the operation of high-power switch-testing circuits, the measurement of a wide variety of characteristics of interest in the operation of power-transmission systems, and simulation of the behaviour of complex networks particularly under transient conditions.

" Electronic Measurement and Control for Industry " was the subject of a paper by J. R. Boundy, B.Sc., A.M.I.E.E. (Evershed and Vignoles, Ltd.), on Thursday morning, September 4th. This paper described an electronically operated controller and its associated apparatus, and gave a brief description of a form of converter for changing the various physical quantities to be measured, such as level, pressure, flow, &c., into a d.c. current varying from 0–30 milliamperes in accordance with the changes in the measured quantity. The three modes of operation of the standard arrangement of process controllers were mentioned, together with the detailed circuit arrangements of this particular controller. The d.c. output from the controller is used to position the orthodox, pneumatically operated process control valve by means of an electro-pneumatic relay mounted on the valve.

The second paper on Thursday morning was concerned with " Electronics in Temperature Control," by D. K. Das Gupta, M.Sc., and R. J. Russell-Bates (Elliott Brothers (London), Ltd.). The authors reviewed the applications of electronics to temperature measuring and controlling devices and assessed associated regulating devices such as transformer voltage taps, continuously variable transformers, saturable reactors and thyratron control.

On Thursday afternoon B. E. Noltingk, Ph.D., A.Inst.P. (Mullard Research Laboratories), surveyed the " Application of High-Power Ultrasonics " and summarised the present position, showing how far different projects have progressed. The applications considered included the dispersion of one material in another, such as emulsification and the production of finely divided suspensions ; the use of ultrasonics for scouring textiles and for the removal of foreign matter from solid bodies ; the ultrasonic tinning of aluminium ; degassing melts and grain refinement ; and chemical effects such as ultrasonic depolymerisation, and the use of ultrasonic vibrations for drilling hard materials.

To-day's session, " User Forum," provides an opportunity for open discussion of user's problems.

BOOKS RECEIVED

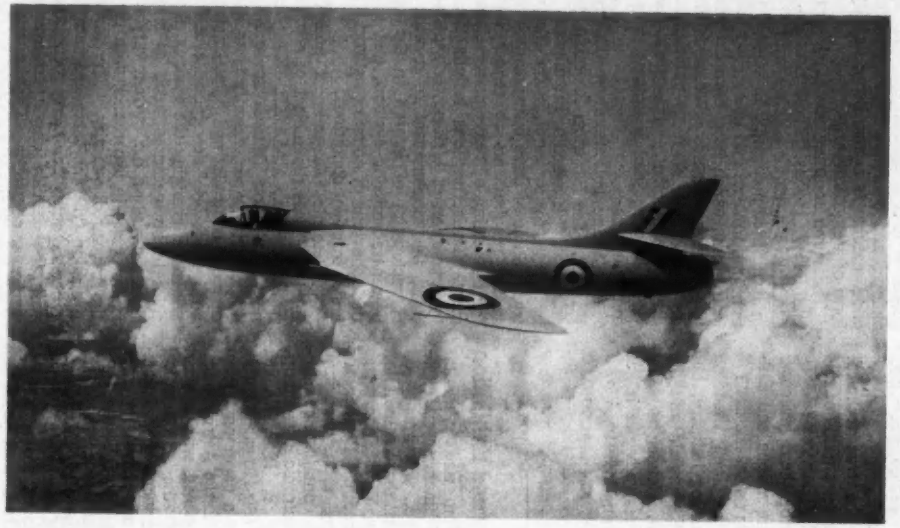
Automatic and Manual Control. Papers presented at the Conference at Cranfield, 1951. London : Butterworth's Scientific Publications, Ltd., Bell Yard, Temple Bar, W.C.2. Price 50s.

Electric Arc and Oxy-Acetylene Welding. Fourth edition. By the late E. Arthur Atkins and A. G. Walker. London : Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 30s.

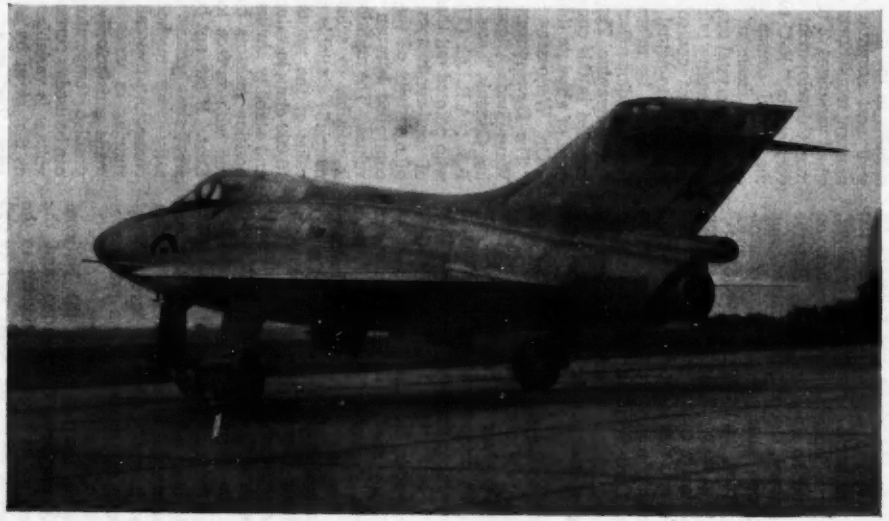
The A.S.E.E. Guide to the Twelfth Edition of the I.E.E. Regulations for the Electrical Equipment of Buildings. Herts : Association of Supervising Electrical Engineers, 54, Station Road, New Barnet. Price 3s. 6d.

MILITARY AIRCRAFT AT THE S.B.A.C. DISPLAY, FARNBOROUGH

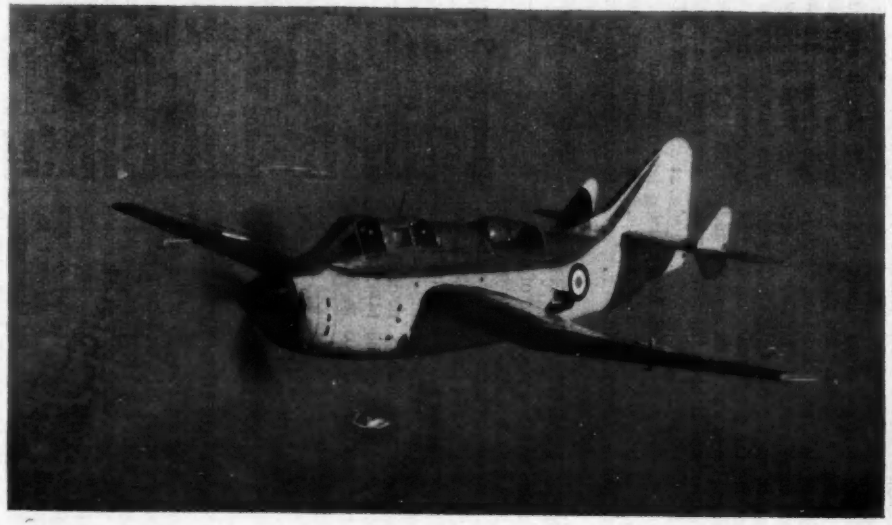
The First Prototype Vickers "Valiant"



The Hawker "Hunter"



Boulton Paul "P120" Delta Research Aircraft



The Fairey "Gannet" Anti-Submarine Aircraft

The S.B.A.C. Flying Display and Static Exhibition

No. I

THE aerodrome of the Royal Aircraft Establishment, Farnborough, is once again the home of the flying display and static exhibition held annually by the Society of British Aircraft Constructors. So great have been the changes in aviation in recent years that it would be difficult to recall a year at Farnborough not outstanding in some respect. But if each year, progress has advanced in steps—large though they have undoubtedly been — perhaps this year visitors to the display would be sorely tempted not to regard progress as having taken a leap. For that is the kind of advance represented by the establishment of the delta configuration in both fighter and bomber roles. As has been announced, the Hawker-Siddeley group has received large orders for a fighter and a heavy bomber of this plan form, and prototypes of both are being demonstrated during the display. The makers affirm also that the delta is ideally suited for large civil aircraft with speeds of about 600 m.p.h.

It is also a year when, amongst other new prop jet transport aircraft, a flying boat, the "Princess," even heavier than the "Brabazon," is able to fly over powered by ten propeller turbine engines; and in the sphere of new propulsion unit developments, mention might be made of the Bristol "Olympus" turbo-jet engine, the first of its kind announced to use a two-shafted compressor and to raise the thrust in pounds to five figures. In fact, so much progress was evident everywhere that one almost overlooked the fact that for the first time at Farnborough it was announced initially that all pilots were to restrict their demonstrations to sub-sonic speeds to avoid annoyance to local residents!

Military Aircraft—Fighters

It is the second prototype "Hunter" interceptor fighter which performed this year at the display. The Hawker "Hunter" is one of the military aircraft which were granted this year super priority production status. As is well known, it is no newcomer to Farnborough, and its less powerful prototypes, from which it derived its final sleek and swept form, have always provoked admiring comment at past displays. Production of this aircraft is being arranged at the Hawker factories situated at Kingston, but mainly at Squires Gate, Blackpool. It has the Rolls-Royce "Avon" axial flow turbo-jet engine. The wing span is 33ft 8in; no other details are disclosed. As is now generally known, the "Hunter" is one of the British aircraft which flies at Mach numbers greater than one during its flight development programme; its speed past the Press enclosure at Farnborough was stated unofficially to be probably in excess of 700 m.p.h. and the height about 15ft.

In the same category of swept-wing, single-seat day interceptors as the "Hunter" is the Vickers (Supermarine) "Swift." It first flew last year and is another of the machines to be accorded super-priority status. Unlike the "Hunter," which made its debut at Farnborough last year, this is the first time that the production version has been shown at Farnborough. Prior to that display the "Swift" had suffered damage during a forced landing and the prototype "535" had deputised. An "Avon" engine is fitted with provision for reheat, as is the case with several other machines. It is a smaller machine than the "Hunter" with a wing span of 32ft 4in and is 41ft 6½in long.

At the time of going to press the fighter aircraft of particularly outstanding interest is the Gloster "GA5" and named the "Javelin." It is like several other British aircraft, capable of transonic speeds and is the first twin-engine production delta aircraft. Our illustrations permit an appreciation of the profile and plan form of this remarkable aircraft. The structural and aerodynamic advantages claimed for this configuration were expressed by the makers in some notes which we included in our description during last year's display of the delta "707A" and "707B" aircraft made by A. V. Roe and Co., Ltd., which, like the Gloster Company, is a member of the Hawker-Siddeley Group of companies. Briefly, it may be said that the triangular wing provides the high degree of torsional stiffness required, and it is simple to construct. The long chord at the root provides damping characteristics which contribute to the elimination of the tail plane on the larger versions. Its other aerodynamic properties remove the need for flaps and other high-lift devices in bomber designs. As a result of its large wing area the wing loading is low, and this was demonstrated at the display, particularly by the "Javelin," by its execution of steep turns near the ground of speeds seemingly in the region of 100 m.p.h. With the long root chord a relatively deep wing is possible in that portion, and the resulting envelope housing engines, fuselage, fuel and load is stated to be inherently more spacious than with any other design. The "Javelin" is fitted with two A.S. "Sapphire" turbo-jet engines, giving over 16,000 lb thrust at sea level.

The two Avro prototypes "707A" and "707B," upon which the theories and claims for big delta aircraft have been largely and, it is claimed, conclusively proved, also gave convincing demonstrations of their handling characteristics.

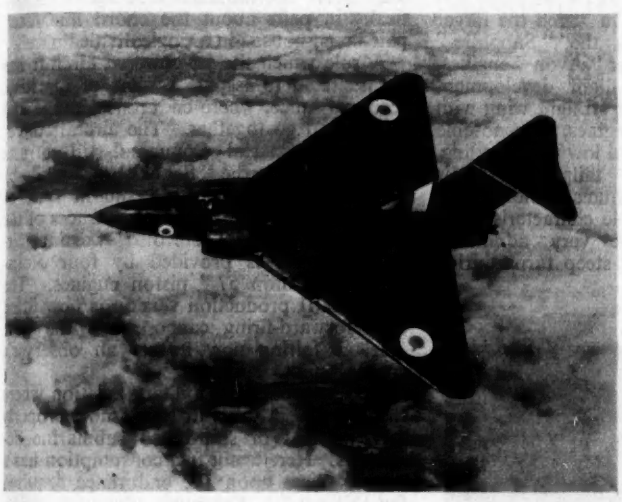
Both this aircraft and the "DH110" were designed for a specification which called for an aircraft capable of carrying greatly increased navigational and interception electronic aids. These are designed to effect the interception, if not the actual destruction of the target, as human scanning facilities are said to be almost totally ineffective at the heights and speeds that future combat is envisaged.

The "Javelin" has been ordered in preference to the "DH110," a twin-tail boom machine with a highly swept configuration, and an aircraft itself quite clearly ahead of any other fighter in the world in respect of its range and speed.

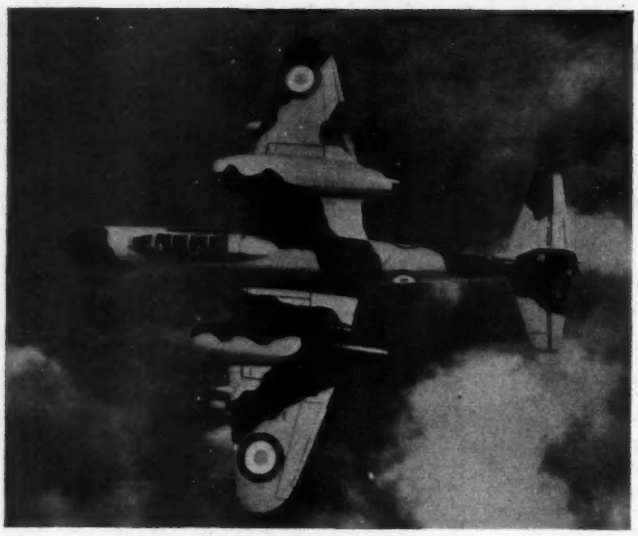
Another delta aircraft, the "P120," made by Boulton Paul and illustrated on page 324, had to be abandoned in the air prior to the show. It was being used for transonic research and had a variable incidence tail-plane as one modification to the earlier version the "P111."

Bomber Aircraft

Since the appearance at Farnborough last year of the Vickers "Valiant" it has been announced that this aircraft, too, is in the super-priority category. Its design is stated to be the most advanced of any production bomber aircraft in the world. It has four "Avon" engines, closely mounted and



The Gloster "Javelin" Multi-purpose Fighter

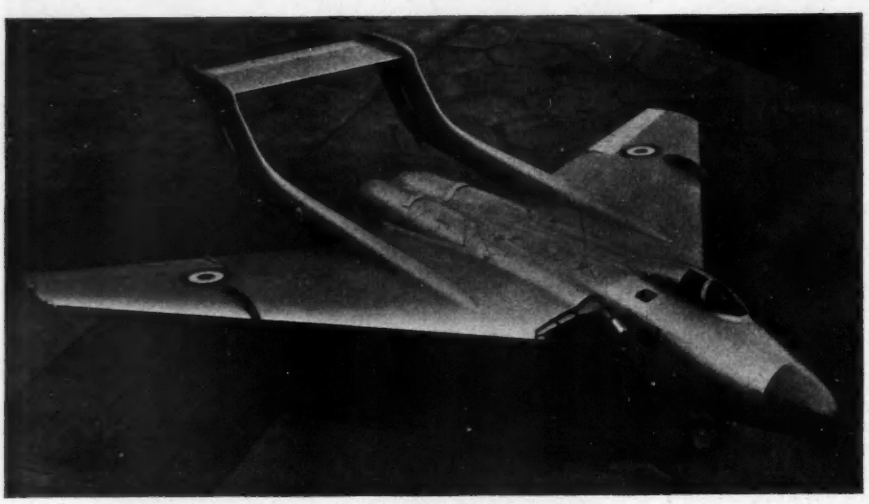


Armstrong Whitworth "NF11" Night Fighter

The Vickers "Swift" Interceptor

smoothly housed within the wing roots. Also mostly conforming with the wing profile are air intakes arranged in the leading edge of the wing root. A point of interest in this heavily swept configuration is the sharper angle of sweep adopted on the leading edge at the root. In all, the "Valiant" might be regarded as a classical example of an aircraft designed, in the light of the more accepted dictates of compressibility factors, to cruise at the highest practicable speed and yet be able to carry and accommodate an effective destructive load over the long distances which seem indicated. It must be borne in mind, however, that experience with the Avro prototypes and the production orders which have now been announced for the Gloster "Javelin" and the Avro delta bomber, the "698," have added great weight to the challenge of the delta configuration. For although at the time of going to press the delta bomber had flown only twice, advocates of this design maintain that in just such a role is it "batting on its best wicket."

The only other jet bomber under super-priority production is the well-known "Canberra" aircraft of the English Electric Company, which first flew in 1949. There are now four different factories producing versions of this aircraft in Great Britain; the Glen Martin Company in America is producing a night intruder version with American produced "Sapphire" engines, and a version is to be made in Australia fitted with "Avons" made there. At the moment it is about the only airframe in which the larger thrust engines, such as the "Sapphire" and "Olympus," and later "Avon" engines, can undergo complete flight development trials. Although it has a straight wing with taper outboard of the engines, it is notable for its low aspect ratio and low wing loading, and variable incidence tailplane. It is known to be very manœuvrable at all heights and to have docile characteristics at low speeds which were very admirably demonstrated, with slow steep turns during the display.



Prototype "DH110" Multi-Purpose Fighter

Another appearance was made by the Short "SA4," which first flew last year and is now being used for general research duties. In its design there is illustrated the method favoured in America of mounting the engines externally rather than burying them in the wing profile. The arrangement is said to lead to a simpler wing structure, as the main spars have not to be "tailored" to accommodate the engines, and arising from this fact the structure is not committed to the size of engine with which it was designed. On the other hand, there appear to be aerodynamic disadvantages at very high speeds associated in particular with the relative frontal areas which obtain. The four "Avon" engines in the "SA4" are mounted well outboard vertically in pairs about the chord line, each pair being housed in a single divided nacelle.

A role which the jet-powered aircraft has yet hesitated to assume is that of maritime reconnaissance, where endurance, range and bomb load go together. The aircraft therefore which Coastal Command still entrusts with this task is the "Shackleton," made by A. V. Roe and Co., Ltd., and in spite of many modifications it still bears traces of the "Lancaster" and "Lincoln" wartime aircraft. Power is provided by four Rolls-Royce "Griffon 57" piston engines. The new Mk. II production version is now fitted with forward-firing cannon, and the rear fuselage fairing now houses an observer's compartment.

Another sphere of military aviation where the pure jet aircraft does not properly serve is that of ship-based submarine destroyers. Here again fuel consumption has a critical effect upon the endurance required for this work. The most advanced British aircraft developed for such duties is the "Gannet," made by the Fairey Aviation Company, Ltd. It first flew in 1949 and is now another aircraft in super-priority production. An important feature in this aircraft is the engine installation, which consists of two "Mamba" propeller turbine engines mounted integrally, but driving separate coaxial counter-rotating propellers. With this arrangement it can obtain the greatest fuel economy by closing one engine down completely and obtaining its required cruising power from the other engine operating at its optimum conditions. It provides in effect twin engine reliability in a single unit. The installation develops over 2900 e.s.h.p. at sea level static.

An aircraft which caused some surprise last year was the Vickers "508" naval jet fighter. Although it mounted two "Avon" engines in the manner of the "GA5" and the "DH110," a thin straight tapered wing was used and it had an unconventional tail unit. The accompanying illustrations of the A.W. "NF11" now in quantity production and the "DH110" exemplify the changes wrought by the requirements of high speed and long range.

(*To be continued*)

Electricity and Productivity

The Anglo-American Council on Productivity has issued a statement reviewing the action that has been taken on the report of the electricity supply productivity teams, and abstracts from this statement are reproduced herewith. It may be recalled that two electricity supply productivity teams (one dealing with generation and the other with distribution) visited the United States of America together in 1949 *and their report was published in* 1950.

Generation

A MAJOR cause of delay in the building of power stations since the war has been the time taken to obtain Ministerial consent, but this is not all wasted. When it became clear that this difficulty was arising the Authority stipulated that discussions with the various Government departments and other bodies should not delay detailed design and layout work. Even so, delays at this stage cannot be entirely avoided under existing procedure, but in an endeavour to reduce them further the Authority is now applying for, and obtaining, consent to develop a power station site although it may not be intended to finish the station until a later extension programme.

Increasing attention is being paid by the Generation Divisions to the planning of construction projects but there is still some difficulty in finding additional staff to carry out the detailed work of layout and design.

The teams noted the development of the "unit" system of a combined boiler/turbine unit without interconnections and the American use of the reheat cycle in station design and they were impressed with the semi-outdoor stations seen. In all the latest station developments in Britain "unit" boiler turbine combinations are being adopted; some ninety-seven unit plants aggregating 4,727,500kW, are planned up to 1956, and one semi-outdoor station is being built. British engineers have accepted the American view that boiler availability is comparable with turbine availability, in spite of differences in the quality of the fuels used in the two countries. The reheat cycle is being considered for three projected power stations and its use is likely to increase.

A great improvement has been made in the speed of the return of generating plant to service after repair by careful planning and by instituting a scheme of priorities for replacement parts.

The use of power tools is more widespread throughout American industry and methods of materials handling have been more thoroughly studied than in Britain. The electricity teams considered that the reason for speedy maintenance in the United States is "the provision of mobile power at the job"; and special tools are developed when required. As a result of the reference to pneumatic impact nut wrenches in the report their use has been very greatly increased in this country.

Main Transmission

The team commented on the larger and more specialised engineering departments in the United States. In Britain the North-Eastern Board employs a limited number of specialists to deal with the design and layout of high voltage systems and related matters.

On the subject of prices, the team reported that the price levels of U.S. electrical plant and apparatus are more realistic than in Britain and that this gives the engineer greater freedom in planning. One example given by the team was that a 1500MVA oil circuit breaker in the United States costs only 27 per cent more than a 500MVA circuit breaker of the same voltage, whereas in Britain it costs almost double. National negotiations are under way to get more realistic price levels for certain equipment.

Network Analysers.—The Merseyside and North Wales Board has adopted network analysers for load calculations in large sections of the system and their use is being extended. The teams reported that since the a.c. network analyser is invaluable for the system planner, it should be regarded as an essential tool instead of a luxury.

Overhead Lines and Cables.—In main transmission the suggestion that armour rods should be used instead of arcing horns on overhead lines has been considered; some preformed armour rods are being obtained from Canada to allow detailed tests to be carried out. The possibility of obtaining circuit breakers of low rupturing capacity at 132kV and 275kV has been discussed with a manufacturer in Britain who is making a study of this and has sent representatives to the United States.

Since there is a much bigger wayleave problem in Britain than in the United States, double-circuit construction has to be used almost exclusively. There is, therefore, little room for the use of "H" type wood pole construction for single-circuit feeders as recommended in the report.

The use of a conductor of a heavier section for the Grid system is not considered desirable. A section of 0·4 square inch for conductors is already the second standard size for the British 132kV system and is to be used as the second standard size on the 275kV system.

Transformers.—The need for reassessment of British design and practice in temperature-rating of transformers has been accepted. The British Standards Institution has considered the revision of the transformer specification and new rating tables are to be issued showing the way in which the rating of the transformer can be associated with typical British load curves. Investigations by the Authority's staff, which were in hand when the productivity teams were abroad, have resulted in the conclusion that it should be safe to operate transformers in emergency where the peak load exceeds the firm transformer capacity by 30 per cent. Research has now been carried out on the use of nitrogen-filling for distribution transformers.

Maintenance.—Hot-line maintenance, or maintenance carried out while the conductors are live, has been considered; it is necessary in the United States because single-circuits are common, but in Britain double-circuit construction is necessary for other reasons, particularly the wayleave difficulty. Hot-line maintenance of high-voltage overhead lines can only be carried out when the humidity is less than about 70 per cent. Because of the limited time during which this occurs here adoption of this method is not thought to be worthwhile.

The same argument applies to hot-line tower painting. The question of some modification of safety rules is being considered by the safety committee of the N.J.A.C. The American method of painting by using only one coat of a special paint instead of two or three of normal quality is more likely to be followed in this country; its advantages in saving time and labour are being considered.

Aerial Surveys.—Aerial surveys to obtain line profiles do not offer the same advantages in Britain as in the United States, although limited use is being made of them. Line patrolling by helicopter has also been considered, but it is thought to be uneconomic under British conditions. The Midlands Board has used a helicopter to lay a 1280ft span of a 66,000V transmission line across a densely wooded valley in the Malvern Hills to provide an alternative supply to Herefordshire. Though spectacular and rapid, the method is unlikely to be other than an occasional device.

Distribution Engineering

Standards of Continuity.—The team drew attention to the American policy of setting a standard of continuity to suit particular circumstances. Yet apart from the low-voltage system in the heavily loaded city centres they were doubtful whether the record of continuity in the United States is as good as in Britain, because the extensive overhead systems are more vulnerable and the weather also is more severe. The whole subject has been receiving careful consideration by the Authority and by the Boards. The Eastern Board has adopted a policy of considering the requirements of different classes of consumer separately and relating the cost to the consumer to the degree of continuity necessary. Thus standards have been relaxed in some parts of the area while in others they have been improved and substantial overall economies have been achieved as a result.

System Planning and Design.—The scientific planning of system developments impressed the team; such planning requires elaborate and detailed statistical and operational records. Several Boards have been or are developing the use of more elaborate statistical records by statistics sections, to allow closer control of their activities.

The South Eastern Board's policy has always been to use out-door substations wherever applicable. The South West Scotland Board considers that the American practice of using out-door switchgear and out-door substations might be adopted with advantage in Britain, especially for smaller sub-stations; out-door substations comprising 11kV switchgear and 11kV/415V transformers, could be adopted as completely metal-clad units. The only objection to this practice is likely to be from town and country planning authorities.

Surge Diverters.—Investigation into the effects of atmospheric disturbance is being undertaken by the Authority in collaboration with the Electrical Research Association and results are expected within the next two years. The Eastern Board has given particular attention to the use of surge diverters and many installations, which use surge diverters on the transformers connected to overhead systems, exist in those parts of the Eastern Board's Area where trouble from lightning is prevalent. Surge diverters are not used on 11kV lines but are used to some extent on 33kV lines by the South West Scotland Board.

Switchgear.—One of the more interesting suggestions made in the report was that high-speed reclosing could be extended at all voltages in overhead circuits in Britain, leading to reduction in the number of interruptions to electricity supply. The team considered that the use of high-speed reclosers in conjunction with time delay fuses on the 11kV and 6·6kV rural lines would improve the continuity of supply and make a saving in operational costs that would probably offset the cost of the equipment. The Midlands Board has imported about fifty automatic reclosers from the United States and has determined their characteristics at its testing station, in order to report on them to the Authority and to give assistance to British manufacturers in developing this equipment. The Eastern Board has already fitted automatic reclosing features to overhead circuits in various parts of the area with satisfactory results. The North Western Board plans to apply an auto-reclose circuit breaker to its rural networks as soon as it finds a model which is both satisfactory and cheap. The South West Scotland Board makes wide use of arc suppression coils instead of high-speed reclosing.

Transformer and Voltage Regulators.—Forced oil circulation and air blast cooling are standard practices in Britain for large transformer units. The Eastern Board considers that the question of whether extraneous apparatus should be added to transformers, which are almost 100 per cent reliable, has to be critically examined.

The Midlands Board is shortly installing a large transformer which will be the first in Britain to be constructed for operation with nitrogen atmosphere. The team reported that in the United States all modern transformers seen of greater capacity than 10MVA were nitrogen-gas-covered, which allows higher operating temperatures and reduces fire risk. In Britain trouble has probably been limited because of the conservative loading of transformers, but agreement has now been reached between the Authority and the Boards that transformers may be operated at much higher ratings in the future. Thus,

nitrogen may have to be adopted to prevent oil deterioration.

The temperature method of loading transformers is found everywhere in the United States. The Midlands Board has reported that in some of the progressive undertakings from which the Board was formed transformers were operated on a thermal-rating basis and that this practice has been extended. As a result of information acquired by the productivity teams, considerable advance has been made in this practice; the maximum load which can be put on the Board's transformers is not now determined by name-plate rating but is dependent upon the load cycle and the temperature rise in the transformer under load conditions. The North Eastern Board also uses the temperature basis of assessment and other Boards are considering its use.

The South Eastern and Eastern Boards are considering the use of completely self-protected (C.S.P.), pole-mounted, low iron loss transformers, which are becoming generally used in the United States; the C.S.P. transformer combines in one tank assembly the power transformer, the low-voltage circuit-breaker and also protection and control devices. No equivalent units are, however, available at present on the British market.

The electricity teams found, as did other teams, that preventive maintenance is the keynote in American industrial practice, and that it is usual to have a separate department dealing solely with routine maintenance. The Eastern Board reports that it is instituting uniform maintenance throughout its area for the more usual items of plant and equipment. It is also considering the economics of setting up centralised sub-area maintenance gangs for particular items such as transformers.

Urban Distribution

Mechanical Hole Boring.—The use of mechanical digging machines, complete with lifting jibs to handle poles, enables the replacement of poles in the United States to be carried out at high speed, even in residential districts. This suggestion has caught the imagination of a number of the local advisory committees. The North Eastern Board is carrying out tests with a pole hole boring machine.

Cold Compression Jointing.—A number of Boards are interested in the development of cold compression jointing. In the cold compression method the copper sleeve on the conductor cores is indented by means of a special hydraulically operated tool so that the sleeve and the conductor strands are compressed into an apparently solid section. The tool is used in jointing both high voltage and low voltage cables and in overhead work. The operation saves much time and labour.

Solid Networks.—The general practice in the more important centres of America of running the low voltage supply networks solidly interconnected as a grid has advantages in increasing the continuity of supply. The main disadvantage is that a shut-down covers an extensive area for a long time. The South West Scotland Board considers that this practice if operated to a limited extent might be advantageous, but it is unlikely that it would be adopted generally in Britain.

Rural Distribution

Conductors.—The Midlands Board, as a result of information gained from the American visit, has progressed in the development of lightweight compression tools making compression-type joints. The more ready use of aluminium as the conductor material for low voltage overhead distribution really depends on the adoption of this method of jointing. In the United States steel-reinforced aluminium conductor is very widely used.

Single-phase supplies, which are general in America for rural areas, have been adopted by many Boards in this country to a limited extent; the practice is now being extended.

Power and Communication Circuits.—The most obvious difference in the United States from British practice is the joint use and ownership of poles for both power and communication circuits in overhead line construction. Agreement has recently been reached between the Electricity Authority and the Post Office authorities to allow the common use of existing power supply and telephone poles. It is not expected, however, that joint usage will be on the same scale as in the United States, where high voltage as well as low voltage lines are mounted on the same poles.

Mechanical Aids.—The Electricity Supply Teams reported that the greatest use is made of mechanical aids to speed or cheapen the job and that the standard of finish did not appear to be as high as in Britain. Mechanical aids which are in use by some of the Boards are compressors, compressed air tools, mechanical breakers and rammers, tractors, thrust-boring machines and digging machines. Many Boards would like to use more mechanical aids but limitations in capital expenditure and lack of supplies have stood in the way of the extension of their use.

Radio Communication for Maintenance.—Several Boards report that radio-communication for maintenance purposes has been used in their areas since nationalisation. The practice is likely to be extended when more high frequency radio equipment is available.

Meter Practice

Out-Door Meters.—One of the comments of the teams which has caused a lot of interest in the local advisory committees and elsewhere is that small capacity meters are frequently erected outside American buildings, and that pre-payment meters are not used. If pre-payment meters were abolished, billing would be necessary more frequently than quarterly, thus increasing accounting costs, although the use of outdoor meters would in part offset this increase. The use of outdoor meter mounting would probably only be possible in new buildings and would, of course, depend on a satisfactory outdoor model being commercially available.

Quality Standards of Electrical Appliances.—There is nothing in this country as yet which exactly corresponds to the checking of quality standards of electrical appliances by the Underwriters Laboratory Incorporated in America. The team was impressed by it. The British Institute of Standards has a certification mark which is applied to technical goods and denotes conformity to defined British standards; the scheme, however, is being extended to apply to consumer goods. The British industry has for some time considered the establishment of a central organisation for checking the quality of electrical goods. Most Area Boards make arrangements for testing specimens of appliances before they are sold in the various Boards' service centres. The Electrical Development Association also has a testing house to which manufacturers as well as retailers can send appliances for examination.

Progress in the Unification of Engineering Standards

Copies are now available from the British Standards Institution of the official, sixty-four page report of the A-B-C (American, British, Canadian) Conference on the Unification of Engineering Standards, held in New York from June 2nd to 5th.

Many people in the engineering industries are familiar with the background to the A-B-C Unification programme, which arose out of disastrous and costly wartime experiences due to the limited interchangeability between the Services equipment of the three countries. The first step to overcome this difficulty was the 1945 Ottawa conference arranged by the Combined Production and Resources Board. From this arose the "Declaration of Accord," which established a system of Unified screw-threads for sizes of ¼in diameter and upwards, and was signed by the three nations in 1948.

Exchanges continued between this country and the other two and led eventually to invitations for another full-scale conference being sent out earlier this year by Dr. J. R. Steelman, Acting Director of the U.S. Office of Defense Mobilization. The agenda on this occasion covered five aspects of engineering practice—screw-threads, pipe-threads, gas cylinder connections, limits and fits and drawing-office practice.

Strong delegations from all three countries attended the conference. The British team of twenty-five was led by Mr. Stanley J. Harley, Chairman of the Engineering Divisional Council of B.S.I., who was supported by Mr. S. W. Rawson, Director-General Machine Tools, Ministry of Supply; Sir William Stanier and Mr. H. A. R. Binney, Director of B.S.I. The Americans sent no fewer than ninety-four high-level representatives of industry, the Services government agencies and standards bodies, and Canada was also fully represented.

The keynote of the conference was set at the opening session on June 2nd, when Mr. Stanley Harley said that the British delegation had come in a somewhat critical spirit—critical of themselves and of the lack of progress in some of the projects discussed at Ottawa in 1945. To ensure speedy and decisive action on this occasion it was agreed that the conference should split into five separate working committees, each one to deal with a single item on the agenda, and to report back to another full session on June 5th.

In three days of long and late sessions all five committees made useful progress. Not the least achievement was the clarification of those fields where long-established differences in practice in the three countries made it impossible for their national standards to be altered. Frank recognition of these conditions cleared the way for productive discussion and decision on other matters.

The range of agreement reached on acme and buttress threads, on limits and fits and on drawing-office practice is set out in the published report now available.

"Continuing Committees," with representatives from all three countries on each, were set up to progress the work started at the conference. The British members of these committees are:

Screw-threads: Mr. S. W. Rawson, Ministry of Supply (Chairman), and Mr. F. H. Rolt, National Physical Laboratory.

Pipe-threads: Dr. J. S. Blair, Stewarts and Lloyds, Ltd.

Gas Cylinder Connections: Mr. N. R. K. Wheatley, Ministry of Supply.

Limits and Fits: Mr. H. G. Conway, British Messier, Ltd.

Drawing-Office Practice: Mr. T. R. Houston, English Electric Company, Ltd.

These gentlemen will keep in touch with their opposite numbers in each of the other two countries and a further progress meeting in New York is planned for mid-October.

In the meantime arrangements are far advanced for the signing of formal agreements under which the Unified screw-thread will become the standard for the armies of all the A-B-C countries. Many of the American manufacturers concerned in the production of Services equipment have already turned over to the Unified thread, and it is steadily being adopted both in Canada and the United Kingdom.

Copies of the conference report may be obtained, price 7s. 9d., post free, from the Sales Branch, British Standards Institution, 24, Victoria Street, London, S.W.1.

Books of Reference

Tatsachen und Zahlen, 1951. Sixteenth edition. Edited by the Verband der Automobilindustrie E.V. Published by VDA-Wirtschaftsgesellschaft, Frankfurt, a.M. Price 12 DM.—"Facts and Figures, 1951" is the title of this fourth post-war edition of the traditional year-book of the Verband der Automobilindustrie, the German equivalent of the Society of Motor Manufacturers and Traders. The book gives a surprising amount of varied information on motoring matters in the form of a statistical survey. It contains extensive data about most items connected with the German automobile industry; in particular are figures on production, new vehicle registrations, exports and on the consumption of steel, coal, rubber, fuel and oil. An international part deals with the same materials, as far as other automobile producing countries are concerned, and offers interesting comparisons. A report on road safety contains a statistical survey of all road accidents, investigated by the authorities, and a careful investigation of their causes. The book is well compiled and ought to be of value to engineers as well as to economists, who are interested in the motor industry or in motorised traffic.

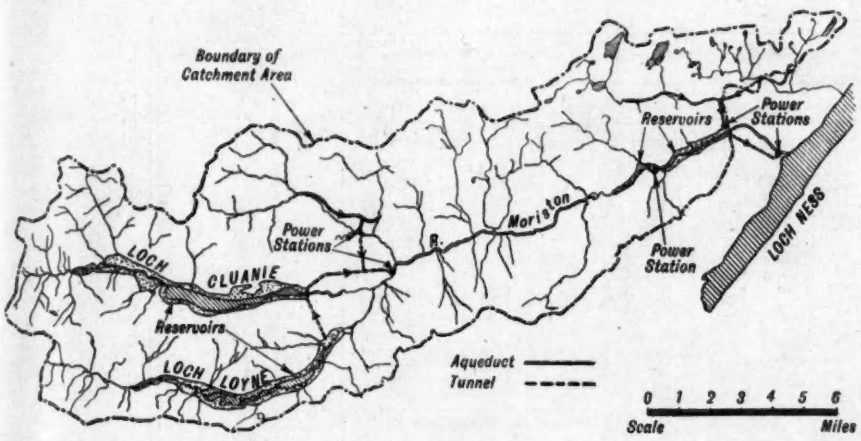
Underground Power Stations in Scotland

THE North of Scotland Hydro-Electric Board has announced that the Glen Moriston hydro-electric scheme, which is situated in Inverness-shire and Ross-shire, has been considerably modified in its design. The principal change has been to substitute underground power stations for the more conventional surface structures of the original design. The estimated annual output of the scheme, which is 214 million kWh, will remain unaltered.

The accompanying map shows the layout of the Glen Moriston scheme as originally designed and published by the Board in 1948 (THE ENGINEER, May 21, 1948). The main storage is provided by two reservoirs, Loch Loyne and Loch Cluanie, each formed by enlarging existing lochs with a dam, and connected by a tunnel, with a second tunnel leading to the principal power station near Ceannacroc. Power is to be generated from the catchment of a northern tributary of the main stream at a subsidiary power station, discharging into the tunnel supplying Ceannacroc power station. The lower part of the scheme originally consisted of a dam and power station at Dundreggan, with a dam forming a second reservoir immediately below it. Diversion works from this reservoir were to lead to a power station beside Loch Ness; again, a subsidiary power station was to utilise the flow from a northern tributary, discharging into the second reservoir.

The design of the lower part of the scheme has been considerably modified, and the lower reservoir will not be built. An underground power station will be constructed almost vertically below Dundreggan dam, with a long tail-race tunnel discharging in Loch Ness near the former power station site. The subsidiary generating station will now be situated above Dundreggan dam, to discharge into the reservoir. In the upper section of the scheme it has been decided to build the principal power station underground. There will be two 16MW sets in the Dundreggan power station, and one similar 16MW set at Ceannacroc, and also a 4MW set.

The underground hydro-electric power station has been developed in several Continental countries in recent years, with the idea of giving greater economy in construction over a surface structure. This is the first major example of its use in the Board's schemes (the small power station at Morar is partly hewn out of the rock and the subsidiary power station of the Affric scheme at Mullardoch reservoir is underground), and it is stated that the Board will have economised to the extent of saving 1400 tons of steel and 25,000 tons of cement by the change. Construction of the scheme was delayed by the Government's restrictions on capital expenditure, thus allowing an examination of possible economies to be made. Amongst other things, it will not now be necessary to build a 132kV transmission line between Dundreggan and Invermoriston, and there will be advantages from the point of view of amenity in the lower part of the scheme. Work has now begun on the construction of the dams at Loch Loyne and Loch Cluanie, and the driving of the tunnel from Loch Cluanie to the power station. The consulting engineers for the scheme are Sir William Halcrow and Partners for the civil engineering, and Messrs. Kennedy and Donkin for the mechanical and electrical aspects of the project.



Original Design of Moriston Project

A Range of 3½kVA Generator Sets

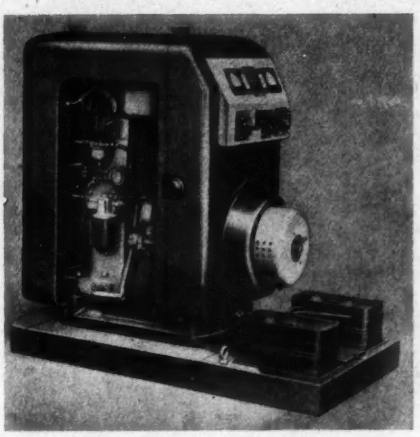
THE accompanying illustration shows one of a new range of self-contained 3½kVA generating sets designed primarily for the export market and produced at the Coventry factory of Star Engines, Ltd. The sets are built to provide a.c. supplies at 110V or 230V, 50 or 60 c/s single or three-phase, and they can be supplied with hand, press button, fully automatic or remotely operated starting controls.

Each "Lynx" set consists of four main components—a single-cylinder industrial engine, a 3kW alternator and a control box—mounted on a light alloy base. The engine, which was specially developed to provide low fuel and lubricant consumption, is a vertical, single-cylinder, four-stroke, cold starting, solid injection diesel engine, both water and air cooled.

For ease of maintenance the steel-backed main bearings, which are pre-finished and lined with white metal, can be replaced without any "fitting"; this facility also applies to the precision steel-backed, copper-lead, indium-plated big-end bearing. A new dry iron cylinder liner can be fitted with equal ease. The crankcase and integral sump are cast in non-corrosive silicon-aluminium alloy. An oil bath air cleaner and a large lubricating oil cleaner are fitted as standard.

A bore of 82·5mm and a stroke of 105mm give the engine a cubic capacity of 662 c.c. It is governed to a maximum speed of 1500 r.p.m. and develops 5½ b.h.p. at the twelve-hour rating. The governor, operated by the camshaft timing wheel, controls the fuel injection, automatically allowing extra supplies to facilitate starting. A flexible coupling connects the engine to a ventilated, drip-proof, self-regulating alternator, built to comply with B.S.S. 168. The alternator is spigoted to the machined magnesium alloy base casting and the engine is located by dowels, so that accurate alignment both initially and when servicing is easily achieved. This basic unit, with the addition of a control cabinet housing the necessary meters, switches and fuses comprises the "Lynx" Mark I hand-starting set.

The Mark II set, illustrated on this page, has press-button starting and is mounted on a fabricated sub-frame extended to carry two 12V, 57Ah Exide batteries connected in series. In this equipment the control cabinet contains (besides the meters and fuses) an adjustable-band voltage regulator, a starting relay, a battery charge indicator lamp, and a main on/off switch. The starting contactor, battery charging resistance and cut-out and indicator lamp relay are housed in an auxiliary box mounted on the bulkhead. When the starter button is pressed the batteries energise the starter windings of the alternator through a relay for a period of 10 seconds, after which the current is automatically switched off to avoid any undue drain on the batteries. The engine should fire as soon as the previously depressed decompression lever is released. The batteries are automatically recharged whilst the set is running and when they are at full capacity the current is automatically switched off.



3·5 kVA Mark II "Lynx" Generator Set

A more advanced unit is the "Lynx" Mark III, which is an automatic set. It is outwardly similar to the Mark II set except that it has a larger control cabinet housing the additional apparatus—a manual and automatic switch, a bridge rectifier, a choke and a start/stop relay. The Mark III unit starts as soon as a minimum load of 60W is switched on and continues to run until the last light or appliance is turned off. Fuel supplies are then stopped automatically and the engine comes to rest in about 35 seconds.

The last equipment in this series, the "Lynx" Mark IV set, is similar to the Mark II but with the addition of a remote control switch-box, which can be conveniently situated some distance away from the set. Mercury relays are used for decompression, starting-stopping functions, and are housed in the main control cabinet. All Star "Lynx" generating sets are fully "tropicalised," finished in deep red and powder blue, and fitted with output plugs and sockets for easy connection to lighting and power circuits.

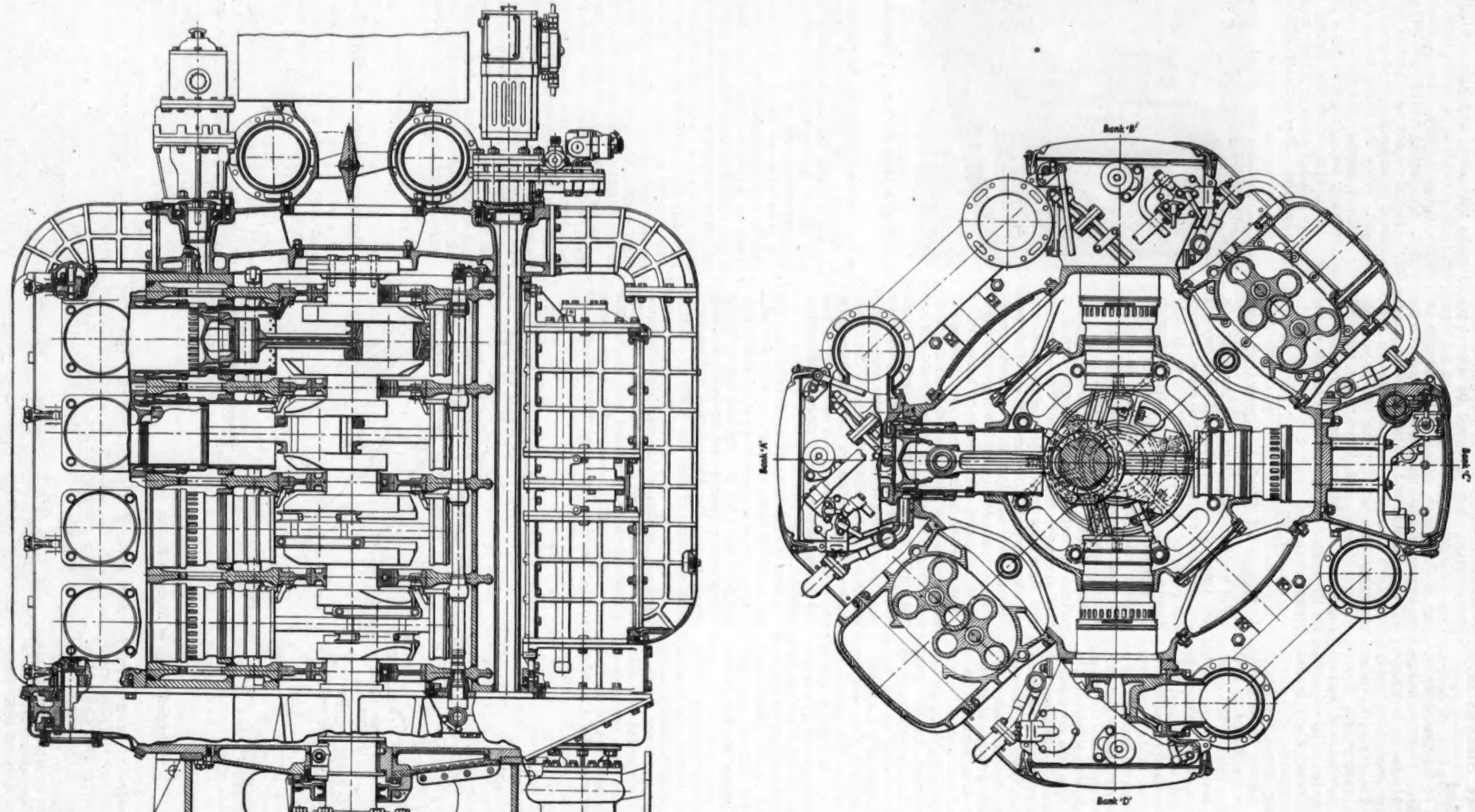
Stress Finder for Ship Loading

A MANUALLY operated device which computes in advance the effects of loading a ship to any proposed plan has recently been produced by Kelvin and Hughes (Marine), Ltd., of London. The Kelvin Hughes stress finder is simple to work and demands no mathematical ability on the part of the operator apart from that required to solve elementary problems of addition and subtraction.

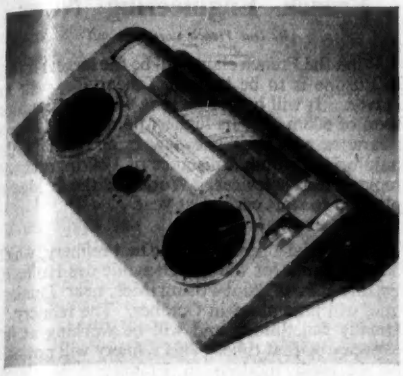
To operate the instrument the individual items of the proposed loading plan are fed into the stress finder through the medium of two pointers and circular scales, one each for the cargo spaces forward and aft of amidships. A deadweight scale is provided and is operated by a separate control.

The stress computation is automatic and takes place progressively as the loading pointers and the deadweight control are moved to take account of the loading items. The whole operation takes only a few minutes to complete, after which the longitudinal scale is consulted

SIXTEEN-CYLINDER VERTICAL RADIAL DIESEL ENGINE



Longitudinal Section and Sectional Plan of Engine



Stress Finder for Ship Loading

and this clearly indicates whether the loading arrangements will cause the vessel to be subjected to excessive hogging or sagging stresses. From the same scale the draughts and trim in the loaded condition can be read. The instrument, which is of clean design and strongly constructed of metal, is supplied in a polished wooden case measuring about 2ft 6in in length by 10in wide by 4in high and, being only a few pounds in weight, can be easily carried.

Industrial Translucent Lighting Units

We illustrate on this page one of a new series of Holophane industrial translucent lighting units. They embody prismatic reflectors and have been designed for factories, power stations, aircraft hangars, and other lofty interiors where the intention is to provide, by light control, a satisfactory degree of ceiling brightness without reducing the illumination on the working plane.

The fittings are made in both single and twin units, the single fittings being designed for tungsten filament lamps, while the twin units employ a mercury discharge lamp, together with a filament lamp—a combination which provides a colour blend approaching that of daylight.

The units embody heavy duty glass reflectors having internally reflecting prisms, which are resistant to heat and depreciation and are

Industrial Translucent Lighting Unit

designed to provide a high standard of light control and efficiency. They are made in three types: extensive, intensive and focusing. All metal parts are of heavy gauge steel, protected against rust and are finished a light battleship grey or aluminium, depending on the type of fitting. Maximum ventilation is provided to ensure that the wiring is kept cool.

Single unit fittings, one of which is illustrated herewith, may be mounted on chain or conduit, while twin fittings are usually supported on chain, for which suspension hooks are provided. The fittings described above are designed and made by Holophane, Ltd., Elverton Street, London, S.W.1.

American Engineering News

(By our American Correspondent)

A Sixteen-Cylinder Vertical Radial Diesel Engine

As part of the current American defence programme, the Cleveland diesel engine division of the General Motors Corporation was commissioned to develop a sixteen-cylinder, vertical, radial diesel engine of lightweight construction. Certain details relating to this interesting engine have now been released by Eric R. Brater, assistant chief engineer of the company, in a paper which he presented at the recent summer meeting of the Society of Automotive Engineers in Atlantic City, New Jersey. A longitudinal section of the engine is shown on page 330. It operates on the two-cycle uniflow principle at 600 r.p.m., and is arranged with four rows of four cylinders each, having 90 deg. spacing between the banks. The bore is 6in and the stroke 6½in. The four connecting-rods in one row are acting on one crankpin, and are located in the same plane. The steel pistons are oil cooled by spray nozzles, and also through the drilled connecting-rod. The barrel-shaped crankcase is built up entirely of steel forgings which are welded together. The crankshaft is made of alloy steel, counterweighted to give good engine balance. Air is supplied to the engine by four Roots blowers. There are thirty air intake ports in each liner, which are covered and uncovered 49 deg. before, and 49 deg. after, bottom dead centre. Four exhaust valves are situated in the cast iron cylinder head. The ball bearing-mounted accessory gear train is at the bottom of the engine. It drives the camshafts, blowers and water pumps, and through extension shafts, the air starting motor, governor, fuel pump, and tachometer, which are mounted on the top of the engine. The overspeed trip mechanism, which is flyweight operated, is mounted on the upper end of the crankshaft. In case the engine overspeeds, the air emergency shut-down valve between the air intake and blower is closed by the overspeed trip which shuts off the air and stops the engine. The cross section of the engine shows one row of pistons, connecting-rods and cylinders, the Roots blowers, and the exhaust manifolds.

Due to the crank arrangement employed, it was found impossible to balance each individual crank throw completely, but the crankshaft and the engine as a whole are completely balanced, there being no unbalanced forces or couples. The crankshaft is balanced statically and dynamically by clamping balancing collars on the crankpins during the balancing operation. These collars are equivalent in weight to the large end of the connecting-rod.

Slipper connecting-rods are used. A segmental bearing shell about ¼in thick is dovetailed into the crankpin bearing end of the rod to facilitate easy removal and replacement in service. The shell is lined with bronze 0·015in to 0·020in thick and a 0·001in thick lead-tin overlay. The connecting-rods are made of a high-grade alloy steel and are machined all over, and retainer rings hold the connecting-rods on the crankpin. Each retainer ring is made in two halves, bolted together, and is free to rotate on the pads of the connecting-rod. Although in a two-cycle engine it is generally assumed that the force on the piston is always directed toward the crankshaft, at high speeds there is a slight reversal in load which must be taken by the retaining rings. The ring bolts are made with right-hand and left-hand threads, so the ring halves can be drawn together at the same time by turning both bolts simultaneously. The pistons are made of a high-grade alloy steel. The crown is a steel forging, flash-welded to the skirt under the ring belt. A trunnion which carries the wrist pin is bolted to the inside of the piston. A floating wrist pin bushing is used, which has spiral oil grooves machined on the inside and outside of the bushing. The oil scraper rings are loaded by inner expanders to reduce oil consumption. The piston cooling arrangement includes stationary, dual spray nozzles with 0·098in diameter orifices which project a constant stream of oil through two taper holes in the crankcase through identical holes on the opposite (bottom) side of the trunnion. The cylinder is of two-piece water-jacketed construction, consisting of a mild steel liner and jacket, the inner surface of the liner being chrome plated and honed.

The jacket is sealed at the bottom with two synthetic rubber seal rings. A baffle plate is provided at the inlet to deflect the water circumferentially for efficient cooling. From the jacket the water flows through brass ferrules into the cylinder head. There is no cooling below the air intake ports. The cylinder is seated in the barrel forging and outer deck forging of the crankcase, and is held in the crankcase by the cylinder head. Synthetic rubber seal rings seal the air box from the inner crankcase. There are thirty air intake ports in the cylinder which admit air from the air box. The joint between the cylinder and the cylinder head is made gas-tight by a bronze gasket ring.

Engineering Conference of the American Institute of Steel Construction

At the Fourth National Engineering Conference of the American Institute of Steel Construction, held recently at the Hotel Commodore in New York City, the attendance was the highest on record. The sessions opened with detailed descriptions of two unusually interesting steel-framed structures which have been recently completed in New York City. One was the United Nations General Assembly Building, and the other was Lever House, a lightly loaded steel-framed office building. Construction details of the United Nations General Assembly Building were presented by Captain Emil H. Praeger, of Madigan-Hyland. After a general description, Captain Praeger emphasised some of the problems encountered in designing and erecting the dome of the structure. The dome is composed of twenty-four ribs curved to a radius of 73ft 1in and thrusting outward against a tension ring made of a series of bent 24in wide-flange sections spliced together. The dome could not be riveted until the supporting members were at the final dead load elevations. These elevations are normally produced by the weight of the superimposed materials, which, of course, could not be installed until after the riveting was completed. Several methods of solving the problem were studied. Eventually it was decided to pull the cantilever tips down to nearly final position by means of cables, and then to make connections of cross bracing between supports, rivet up the entire dome, apply the dead loads and then cut the cables. If all calculations were correct the dome would then be freely floating in a position of equilibrium. Calculations indicated that if the cantilevers were pulled down to a position ¾in above the final position, cable loads of workable magnitude could be employed. To compute these loads it was necessary in one case to solve eight simultaneous equations, one for each of eight cantilevers. After all preparations and calculations had been made, the cables were tightened in groups until the pre-computed cable loads had been reached. The average error between the actual tip elevation and the computed elevation under load was ¼in to ¾in, which was corrected by shims placed on top of the cantilever tips.

Lever House, employing lightweight floors and lightweight walls, was the subject of an address by Walter H. Weiskopf, of Weiskopf and Pickworth. This building, Mr. Weiskopf pointed out, is a reflection of the economics in design and fabrication permitted under up-to-date building code regulations. The relatively lightweight construction of the building has several important effects on the structural steel design. One is a change in the ratio of live load to dead load in the floor construction. The live load is the same but the floor construction itself is much lighter. He also pointed out that the beams were not encased in stone concrete and that deflections of the beams under the vertical loads had to receive more consideration than in other types of designs. Similarly, wind deflections had to be studied more carefully. Since the building itself is lighter, the dead loads are smaller and all the members are smaller. Therefore wind stresses are proportionately greater than in a building using old-fashioned materials and construction methods.

At a panel discussion of the Institute's research programme, J. O. Jackson, of the Pittsburgh-

Des Moines Steel Company, described the current research projects sponsored by the Institute. He pointed out that changing conditions bring new problems, and improvements in steelmaking and fabricating processes make available new materials and methods which require additional knowledge for proper utilisation. Among the new areas needing further research he listed the design of structures to resist atom bomb attack, the development of information to facilitate the design of tapered steel members, the possible improvement in the physical properties of structural steel that could be obtained by stretching or otherwise cold-working steel and the structural use of alloy steels. Lynn S. Beedle, assistant director of the Fritz Engineering Laboratory at Lehigh University, then reviewed current research on rigid frames. He discussed some results of the work that is being conducted to study the plastic behaviour of structural beams, columns, connections, and frames to observe their reserve of strength, and to explore limitations that may be involved in using the plastic range of steel design. Mr. Beedle concluded his talk by saying that "further consideration needs to be given to the use of the reserve of strength in indeterminate structures. The usefulness of plasticity in structural design is limited by the same factors which cause a modification in present-day elastic design—factors such as brittle fracture and fatigue. When these factors are absent, structures should be designed on the basis of limiting the deflection rather than the stress. Evidence indicates that often this may be done simply, without exceeding permissible deflections or yield point stress at working loads. Although at least one structure has been designed in England by the application of plastic theory, it is thought that its use in the U.S.A. ought to await the further study of some limitations, local buckling being one of the most important."

Research on riveted and bolted structural joints was described by Dr. Nathan M. Newmark, Professor of Structural Research at the University of Illinois. Among the projects he described was the study of the strength of rivets in combined shear and tension; he reported that on the basis of tests and practical experience the Council expects to make appropriate recommendations for design specifications. Results of tests to determine the effect of high bearing stress was also summarised by Dr. Newmark. Its objective is to determine whether bearing ratios of the order of two or more could be used in design without serious reduction in strength. The indications are that for static loading there is no decrease in strength and possibly even a slight increase up to varying ratios of slightly greater than two. The final programme described by Dr. Newmark was to determine if longer fatigue lives are possible with some of the low-alloy steels. Some fifteen different alloy steels are being tested at Northwestern University to determine the relative fatigue strengths under conditions representative of those which might be found in a bolted or riveted joint.

At a panel discussion on problems of welded fabrication, Boyd S. Myers, a consulting engineer of Houston, Texas, described some welded, tier buildings which had recently been built in Texas, particularly discussing ways of controlling deformations caused by the heat of the welding process. He also named the factors necessary to secure a satisfactory and a desirable welded structure, pointing out that accurate shop fabrication, reliable field inspection, and carefully qualified welding operators are among the most important. He mentioned that the use of butt welds to replace the heavy connections required on a riveted structure result in a saving in detail weight varying from 7 to 10 per cent. By using a cellular floor construction the saving may be as much as 15 per cent. Finally, J. R. Stitt, of the R. C. Mahon Company, presented a paper covering ways of controlling shrinkage and distortion in welded structural members. Mr. Stitt recommended a system of alternate welding on opposite sides, whether the section to be welded is a box section with four welds at the corners, a butt weld, or a double-V butt weld welded from the two sides. In general, the technique is to complete about half of a weld on one side, which will fuse and give a heat-affected zone tending to shrink the metal crossways as well as lengthwise. Then, by turning over the section and applying a weld on the opposite side, the tendency will be to counteract the shrinkage from the first weld, leaving the section slightly distorted. Completing the weld on the second side will pull the section still further past straight, but when the section is turned over and the weld on the first side completed the member is finally flat and without distortion.

Construction of Aircraft Carriers for the U.S. Navy

The keel was laid recently at the yard of the Newport News Shipbuilding and Dry Dock Company, Newport News, Virginia, of the 59,900-ton U.S.S. "Forrestal," which, on completion, is expected to be the largest aircraft carrier in the world. The cost of the 1040ft long vessel has been estimated at 218,000,000 dollars. The "Forrestal" is the first U.S. Navy carrier built since 1934 with a flush deck, entirely clear of obstructions. The flight deck will be of steel. She will have four catapults that can launch as many as thirty-two interceptor aircraft within four minutes. Four large elevators will lift the aircraft from the hangar deck to the flight deck. The vessel is scheduled to be launched in March, 1954, and is expected to be ready for delivery in December of the same year.

It has been announced by the U.S. Navy that the sister ship of the "Forrestal," which has been designated as the "CVB-60," pending the selection of a name, will be built at the New York Naval Shipyard in Brooklyn. The U.S. Navy had been under much pressure to let the contract for the new carrier to a private shipyard, preferably on the West Coast, but it has maintained that no private concern except the Newport News Shipbuilding and Dry Dock Company was equipped to undertake such work. The Newport News yard has the "Forrestal" and other construction work to handle: hence it was decided to build the carrier at the New York naval yard. This yard only requires an extension to its crane tracks to be able to handle the size of vessel involved.

Expansion of A.E.C. Gaseous Diffusion Plants

Construction contracts have been placed by the U.S. Atomic Energy Commission for the expansion of its gaseous diffusion plants at Oak Ridge, Tennessee and Paducah, Kentucky. A 464,000,000 dollar addition at Oak Ridge will be built by the Maxon Construction Company of Dayton, Ohio. At Paducah, the prime contract on a 459,000,000 dollar addition to the uranium-235 separation plant now under construction has been awarded to F. H. McGraw and Co., of Hartford, Connecticut. The Carbide and Carbon Chemicals Company, a division of the Union Carbide and Carbon Corporation, will operate both the new plant additions. Funds for the Oak Ridge and Paducah expansions were included in the 1953 Independent Offices Supplemental Appropriation Act, signed by President Truman on July 14, 1952. This measure required the appropriation of a total of 2,986,894,000 dollars for the Atomic Energy Commission.

A Nuclear Reactor for Naval Propulsion

Development work on a nuclear power plant suitable for the propulsion of large naval vessels, such as aircraft carriers, is to be conducted by the Westinghouse Electric Corporation under a contract with the U.S. Atomic Energy Commission. The existing contract between Westinghouse and the Commission has been modified to include work on this new project. The work will be concentrated at the Bettis plant, near Pittsburgh, which is operated by the Atomic Power Division of the company.

A TECHNICAL BOOKS LIST.—A technical books list—with over 5000 titles, under thirty-nine subject classifications, of English and American books now available in this country through the book trade, has been published by the Publishers' Circular, Ltd., 171, High Street Beckenham, Kent, at 2s. 6d. net.

French Engineering News

(By Our French Correspondent)

What the French claim will be the largest bridge in Europe is to be built at Tancarville, near Le Havre. It will be 1410m long with a suspension span of 608m. At its highest point it will have a clearance of 47m. The new bridge will be the only bridge within a distance of 124km, and will replace ferry services. Work on the bridge is planned to start early next year.

* * *

The official opening of the new refinery, which has been built for the Ste Generale des Huiles de Petrole B.P. at Saint-Pol-sur-Mer, near Dunkerque, will take place in October. The refinery is already functioning and will be working at full capacity by that time. This refinery will not only be the most modern in France, it is stated, but one of the finest in Europe. It is situated on the Dunkerque dunes and its construction is considered a feat of engineering. The capacity of the refinery will be in the region of 2 million tons of crude oil per year. The installations cover about 200 acres, including reservoirs, with a total capacity of 500,000 cubic metres. The refinery's plant includes two atmospheric topping installations, capable of handling 6000 tons of crude oil daily, and one thermal reforming plant with a capacity of 850 tons daily.

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The French Minister of Finance has agreed to grant a credit of £825,000 as a first contribution to the electrification of the Valenciennes-Thionville line. At one time, owing to the serious position of the franc, it was decided to hold up this development, but following the setting-up of a European steel and coal pool, the work has been sanctioned. The line will play a very large part in the transport of fuel and metal. The complete cost of the development is estimated at about £15 million, and it is expected to be completed by 1955.

* * *

The French fuel position is improving. Coal stocks have now risen considerably. It is expected, however, that with increased industrial production a fall is likely. The increase is not a seasonal one. The drought which has given agriculture some trouble in France is not likely to affect hydro-electric production, it is stated. In 1949, for example, the reservoirs were only 34 per cent filled at this time; this year the average is over 77 per cent, which is usual at this time of the year. In 1949 the Massif Central reservoirs were down to 3 per cent, whereas this year they are 68 per cent full. Electricite de France states that even if this year had been as dry as 1949 the situation would not have been so serious. Over the past three years construction has gone ahead at a considerable speed so that despite increased consumption the margin of safety is very much wider.

Electricite de France has also announced that a hydro-electric scheme is to be constructed at Grangent on the Loire, some 15km from St. Etienne. It will consist of an arched dam some 200m in length and 55m high, a diversion tunnel 108m long, and a power station with an installed capacity of 32·4MW, generating some 108·5 million kWh annually.

* * *

French Equatorial Africa will have its first hydro-electric power station in service some time next year, it has been announced in Paris. A committee was set up some years ago to examine the possibilities of this part of Africa which has no natural fuel deposits, but is well supplied with potential water power. The electrification programme was drawn up as far back as 1948, but work has been fairly slow and difficulties have been many. A dam has been constructed on the Djoue, a tributary of the Congo, some 12km from the town of Brazzaville. From this reservoir water will be diverted through a tunnel 850m long to the power station. The production aimed at is 120 million kWh per year. An ambitious programme of future works has been planned as it is thought that the development of water power will have considerable economic importance for the area.

Industrial and Labour Notes

Engineering Wages

Last week-end the executive council of the Confederation of Shipbuilding and Engineering Unions discussed the latest statement on engineering wages made by the Engineering and Allied Employers' National Federation. As recorded in these notes last week, the Federation's negotiating committee—whilst maintaining that it could not alter its decision about the rejection of the claim for an increase of £2 a week—undertook to report to the management board of the Federation the representations which had been made by the unions.

The management board reaffirmed the view expressed by the Federation's negotiating committee that the claim was unjustified. If the claim was conceded, its reply continued, grave damage would be inflicted on the engineering industry and sales at home and abroad would be seriously restricted. The management board went on to say that it was unable to make any alternative offer, and expressed the opinion that any general advance in wages would be against the national interest, inasmuch as it must increase costs which would have to be passed on to the consumer with a detrimental effect on sales and on employment.

This was the substance of the statement considered at the special meeting—held on the eve of the Trades Union Congress—of the executive council of the Confederation of Shipbuilding and Engineering Unions. Afterwards, it was announced that the council had expressed its determination "not to accept this position without exercising resistance." It has therefore recommended the executives of the unions affiliated to the Confederation to instruct their members to cease working overtime and to limit piecework. The executives of the affiliated unions are due to meet on September 10th. As these notes go to press the Trades Union Congress, in session at Margate, is debating wages questions and policy.

The Trades Union Congress

The eighty-fourth annual meeting of the Trades Union Congress is being held this week at Margate, under the presidency of Mr. Arthur Deakin, C.H. Mr. Deakin delivered his presidential address on Monday morning. In the course of it he claimed that the general council of the T.U.C. had not failed in its duty in warning the unions of the dangers which beset the national economy and affected the position of the nation in the world of to-day. The general council, Mr. Deakin said, had pointed out that the adverse balance of trade could not be restored without a strong and sustained effort of increased production to meet our domestic needs and sell our products in the markets of the world. It must be remembered, he added, that the island on which we lived was no longer, exclusively, the world's workshop. Many of our economic troubles, Mr. Deakin suggested, arose from that fact. The difficulty would not be lessened if a policy was pursued which inevitably increased the cost of production and compelled exporters to ask higher prices for their commodities in world markets.

Mr. Deakin then went on to talk about wages. From time to time, he said, there was pressure to abandon the long-established policy of wage negotiation in favour of a national tribunal with a responsibility to devise a national wage policy. That, Mr. Deakin observed, was a very convenient term, but it was difficult to find out precisely what the people who advocated it meant. He himself could not think of anything which was more likely to create suspicion among the rank and file than to seek to adjust the present method of wage regulation without a clear idea of what was to be achieved. The formulation of wage policies, Mr. Deakin warned, was not something which could be used as a mere form of propaganda. Demands designed merely to cause unrest in the minds of trade union members—unrelated to reality as they often were and dictated with the intention of buttressing extreme political views—could only be regarded as a betrayal of the real interests of the people the unions represented. The review of the economic situation which was before the Congress made it perfectly clear, Mr. Deakin emphasised, that without a rise in productivity substantial wage increases were bound, in the main, to raise costs. The general council felt that it was impossible to avoid the conclusion that an appreciable increase in the cost of our exports at the present time could only have the most serious consequences so far as our own standard of living was concerned. It would most likely produce a loss of markets and limit the capacity to buy the essential raw materials and food we needed. The trade unions, Mr. Deakin concluded, had a clear duty to act with a full sense of responsibility in this critical period; not to make unreasonable demands and to do all that they could to avoid interruption of work. It was of the utmost importance to keep industry going, with the maximum employment and with steadily rising productivity, at the lowest possible production costs.

Index of Industrial Production

This week the Central Statistical Office of the Treasury has stated that the index number of industrial production (1948=100) has been provisionally estimated at 110 for all industries in June, compared with 115 in May. The figures for the corresponding months last year were 122 in June and 116 in May. It should be borne in mind, however, that the figures for June this year and May last year were affected by the Whitsun holiday.

Analysing the various industry groups, the Treasury's statement shows that in June this year the index number for mining and quarrying was 105, for the manufacturing industries 111, building and contracting 107 (compared with 99 in May), and gas, electricity and water 108. The information so far received indicates that the index for all industries in July—a month affected by annual holidays—will be 104 or 105.

Changes in Wage Rates

Information published by the Ministry of Labour about changes in wage rates which came into operation in July shows that there were increases aggregating approximately £73,000 in the weekly full-time wages of about 324,000 workpeople. Those receiving increases included workers in the general printing industry, glass container making, asbestos cement manufacture, and chalk quarrying.

The Ministry says that of the aggregate wage increase of £73,000 a week in July, about £54,000 was the result of the operation of sliding scales based on the index of retail prices; about £13,000 resulted from arrangements made by joint industrial councils or other joint standing bodies established by voluntary agreement; about £5000 resulted from arbitration awards; and the remainder was the result of direct negotiations between employers and their workpeople. At the end of July the index of rates of wages (June, 1947=100) remained at 129 for all workers, at which figure it had stood since the end of April.

In the first seven completed months of this year changes in wage rates resulted in an aggregate increase of £2,050,900 in the weekly full-time wages of 5,036,500 workpeople in the United Kingdom. In the comparable months of 1951 there were increases aggregating £3,383,000 in the weekly full-time wages of 8,015,000 workpeople.

Trade Disputes

Although, in July, there were fewer stoppages of work through industrial disputes than in June, the actual number of working days lost was greater. Figures published in the latest issue of the *Ministry of Labour Gazette* give the number of stoppages of work through disputes in July as 125—compared with 181 in June—the number of workers involved being 37,800 and the aggregate number of working days lost 277,000. Most of the stoppages were in the coal mining industry, although in the vehicle building industry there were eleven stoppages, which affected 25,500 workers and caused an aggregate loss of 237,000 working days.

There were ninety-eight stoppages of work which actually began in July. Of that number, the Ministry of Labour says, eight arose out of demands for increases in wages, and thirty-five on other wage questions. Twelve stoppages were concerned with the employment of particular classes or persons, forty related to other questions respecting working arrangements, and one stoppage was attributed to a question of trade union principle. Two stoppages were in support of workers involved in other disputes.

In the seven months, January to July this year, there were 1005 stoppages of work through disputes reported to the Ministry. The number of workers involved in them has been estimated at 228,100 and the aggregate number of working days lost at 1,180,000. Last year, in the corresponding months, 1009 stoppages were reported, involving 255,300 workers and causing an aggregate loss of 1,263,000 working days.

The Foreman's Job

A paper by Mr. F. de P. Hanika, of the Royal Technical College, Glasgow, which has just been published by the Institute of Industrial Supervisors, deals with "The Foreman and Works Organisation." In the course of it, Mr. Hanika suggests that foremen in large firms sometimes feel that their opposite numbers in smaller concerns are fortunate because planning, production control, rate fixing and so on do not add up to a full day's work for someone and are therefore left with the foreman instead of being handled by a "functional specialist." On the other hand, he asks, is it not a blessing to be able to shed some of the worries of, say, chasing material supplies or getting labour on to the shoulders of people who have nothing else to do, leaving the foreman free to devote himself fully to running the shop?

Mr. Hanika goes on to assert that that is the job which only the foreman can do. He says "it is so vitally important that it deserves all a good man can give it." Despite all that is said about men being interested only in their pay-packet, is it not a fact, Mr. Hanika asks, that a "happy shop" will turn out more and better work than one beset by stress and strife? The first-line supervisor, the paper continues, is and always will be the hinge on which the industrial effort turns. Not until the foreman's contact with and control of the men and women in his shop have translated orders into productive effort has the firm earned a penny piece.

Coal Exports

In a statement accompanying the annual report of Powell Duffryn, Ltd., the chairman, Sir Herbert Merrett, comments that "much has been said and written about the improvement in our coal export trade, but comparisons have been avoided except with the immediate past." Sir Herbert says the true position is that, as a result of almost unlimited expenditure, it has been stated that coal exports this year will reach a total of 12,500,000 tons, against 36,000,000 tons in 1938. It is hardly worth while, the statement adds, referring to the higher figures achieved earlier in the century.

Coal output, Sir Herbert goes on to say, increased by just over 1,000,000 tons during the first half of this year, but, he asks, what of the home demand, which, unless there is an extraordinary recession in British trade, appears likely to overtake and exceed the potential output progressively? Sir Herbert thinks that we must not be too confident about our ability to sell to foreign customers the qualities of coal not required at home. He says that buyers overseas are already becoming selective and hesitant, and now refuse to take many of the low grades of coal imposed upon them since the war.

Notes and Memoranda

Rail and Road

BRITISH TRANSPORT COMMISSION.—The Minister of Transport has announced the reappointment of the chairman and three full-time members of the British Transport Commission, whose present appointments expired on August 31st, for a further term of one year. They are Lord Hurcomb, G.C.B. (chairman), Mr. John Benstead, Lord Rusholme, and Sir William Wood. The other members of the Commission whose appointments are not affected are Mr. F. A. Pope, Captain Sir Ian Bolton, Bart., Mr. John Ryan, and Mr. H. P. Barker.

ROAD ACCIDENTS IN JUNE.—Ministry of Transport statistics show that casualties on the roads of this country in June, 1952, totalled 19,360, some 389 less than in June, 1951. The killed numbered 382, and the seriously injured 4508. In the first six months of this year road accidents caused 95,157 casualties, of which 2090 were fatal. This is an improvement on the same period last year, when there were 2060 more casualties and 248 more deaths. Provisional road accident figures for July of this year show that 452 persons were killed, 5095 seriously injured, and 15,368 slightly injured, making a total of 20,915, which is 896 less than in July, 1951, although the number of killed is larger by twelve. These figures are subject to minor correction.

REPORT ON THE DERAILMENT BETWEEN LINLITHGOW AND PHILPSTOUN.—The Ministry of Transport has now issued the report of the inquiry into the derailment which occurred on May 25th last between Linlithgow and Philpstoun, in the Scottish Region. The derailment took place when the 8.33 a.m. passenger excursion train from Glasgow to Whitley Bay was passing the trailing points of the Pardovan siding. Four of the train's ten coaches were derailed, but fortunately there were no casualties. The accident, it is stated, was caused by the thoroughly unsafe condition of the crossing as a result of a sub-ganger removing a bolt in the nose of the trailing vee crossing and not having time to replace it before the train arrived. The sub-ganger was not aware that the excursion train was running and when he started the job thought that he had plenty of time to complete it.

Air and Water

BLACKBURN FREIGHTER AIRCRAFT.—The Ministry of Supply announces that it has been decided to place a production order with Blackburn and General Aircraft, Ltd., for the "Universal Freighter" for use by the Royal Air Force.

LAUNCH OF MOTOR TORPEDO BOATS.—The first two of a new design of motor torpedo boat, H.M. "Gay Archer" and "Gay Bombardier," have been launched recently at the Portsmouth yard of Vospers, Ltd. The vessels are almost entirely of wooden construction, the hulls incorporating structural members of water-resistant plywood. These two boats are 75ft 2in in length, with a beam of 19ft 8in, and they mount two 21in above-water torpedo tubes and one small gun. Their main machinery consists of conventional petrol engines, by Packard, Ltd.

THE SEA TRANSPORT OF OIL.—In his chairman's statement accompanying the annual accounts of Vacuum Oil Company, Ltd., Mr. J. C. Gridley says that long-term freighting arrangements have been made to cover a substantial portion of the company's tanker requirements for the import of crude oil from the Middle East. Amongst others, two sister-ship tankers of approximately 32,000 deadweight tons, which are to be built for Norwegian owners, have been chartered for a period of ten years from their respective completion and delivery dates in 1954 and 1955. A contract has been concluded by the company with the Grangemouth Dockyard Company, Ltd., for the construction of a 1640 deadweight tons coastal tanker specially designed for the carriage of lubricating stock oils from the Coryton refinery to the Birkenhead works. It is hoped that the vessel will be delivered in the summer of 1953.

Miscellanea

MINISTRY OF TRANSPORT APPOINTMENT.—The Minister of Transport has appointed Mr. Alfred George Blows to be Registrar-General of Shipping and Seamen with effect from September 9, 1952, in succession to Mr. Alfred Spence.

CORRECTION.—In the article "Metallurgical Topics," on page 287 of last week's issue, we referred, under the heading "Rheotropic Embrittlement," to data obtained by Jenkins and Digges. The data should, in fact, have been attributed to Geil and Carwile.

UNIVERSITY OF LONDON.—The title of Professor Emeritus of Chemical Technology in the University of London has been conferred upon Sir Alfred Egerton, D.Sc., F.R.S., and that of Professor Emeritus of Mining upon Professor J. A. S. Ritson, M.Inst.M.M. Sir Alfred Egerton has been professor of chemical technology at the Imperial College of Science and Technology since 1936, and Professor Ritson has occupied the chair of mining at the same establishment since 1935.

THE NEWCOMEN SOCIETY.—A special general meeting of the Newcomen Society is to be held at the Science Museum, South Kensington, London, S.W.7, on Wednesday, September 17th, at 5.30 p.m. It will be followed by the first ordinary general meeting of the new session when the following papers are to be presented:—"History and Particulars of the Brass Battery Process," by Mr. B. de Soyres, and "Memorials to Engineers and Men of Science," by Engineer Captain E. C. Smith, R.N. (Ret.).

SCHOLARSHIPS IN RUBBER TECHNOLOGY.—We are informed that scholarships to the value of £300 a year for three years, and to be awarded annually, have been endowed by the Dunlop Rubber Company at the National College of Rubber Technology, London.

CORRECTION.—Our attention has been drawn by the British Internal Combustion Engine Research Association to the incorrect spelling of the name of Mr. Miles Beevor in the list of names of the association's newly elected council members, which appeared in our issue of August 22nd.

ALUMINIUM PRICE REDUCTIONS.—The British Aluminium Company, Ltd., announces price reductions, amounting to 2d a pound, or nearly 8 per cent, for bulk quantities, for aluminium thin-gauge sheet and coiled strip for boxmaking and capping purposes. The reductions came into effect on September 1st and follow the completion of substantial extensions to the company's Falkirk rolling mills, including the installation of new high-speed tandem and finishing strip mills.

FILM ON KUWAIT OILFIELD.—On Wednesday of last week we were invited to see a most interesting film entitled "Desert Harvest," made under the direction of the Kuwait Oil Company, Ltd. This film tells the story relating to the discovery of the Burgan oilfield, some 30 miles south of the town of Kuwait. This oilfield has proved to be one of the biggest single oilfields and the most accessible geologically yet discovered and has made Kuwait one of the foremost oil producing countries in the world.

FLAME-PROOF CONVEYOR BELTING.—The Dunlop Rubber Company, Ltd., announces that after twelve months' rigorous tests at its research centre in Manchester, flame-proof conveyor belting it has developed has been accepted by the National Coal Board for use in mines where fire risk is a serious hazard. The belting is stated to be the result of more than ten years' research and development work, which was interrupted by the war. The three new types of belting introduced each incorporate flame-resisting compounds.

COAL OUTPUT.—Coal output in the week ended August 30th amounted to 4,254,500 tons, which included 3,980,500 tons from the deep mines and 274,000 tons from opencast workings. In the comparable week of last year, the total output was 4,400,300 tons. The Ministry of Fuel and Power states that in the first thirty-five weeks of this year the total amount of coal produced was 148,753,400 tons, or nearly 2,000,000 tons more than the total for the corresponding period of 1951. Total distributed stocks of coal on August 23rd were 17,492,000 tons, compared with 13,866,000 tons on August 25, 1951.

GAUGE AND TOOL MAKERS' ASSOCIATION.—The fifth edition of the Gauge and Tool Makers' Association members handbook and buyers' guide index has just been published, and is available on application to the association's offices at Standbrook House, Old Bond Street, London, W.1. This book gives the aims and objects of the association and a survey of its services and activities, together with a complete list of its members and their products. The association has also issued a second edition of its comprehensive brochure giving details of the customs duties and taxes levied by the principal world markets upon the importation of tools and gauges. The countries dealt with include those in Europe, the Middle East, Far East, Latin America, Africa, Australasia, and India, Pakistan, Canada, and the U.S.A.

HYDRAULIC SYSTEMS AND MACHINE TOOLS.—A new edition to the series of technical manuals on questions connected with lubrication, which is published by the Vacuum Oil Company, Ltd., is entitled *Hydraulic Systems, and Hydraulic Oils for Machine Tools*. This book, after dealing with the fundamental principles of hydraulic systems, deals in a clear practical way with their elements and application to machine tools. It then gives operating notes on hydraulic systems and the essential properties of hydraulic oils. The information is supplemented by numerous diagrams reproduced in two colours, which are designed to show in a clear way the principles of the systems described in the text matter. All who are in any way connected with the design, installation or use of hydraulics in machine tools will find this a very useful and interesting book to possess. It is obtainable free of charge from the company's office at Caxton House, Tothill Street, London, S.W.1.

REFRESHER COURSE FOR PLANT ENGINEERS.—The University of Nottingham has issued details of a refresher course on "Heat and Power," which is intended for senior works and plant engineers. The course will be conducted in the New Extension Block, Department of Civil and Mechanical Engineering, University of Nottingham, and will be presented weeky on Tuesday evenings for a period of nineteen weeks, beginning October 28th. The papers will be given by specialists drawn from industry and university, and will be followed by a period for intensive discussion. Advance copies of most papers will be supplied for inclusion in a specially prepared folder. The course, which is a development of an experiment conducted two years ago at Nottingham, has been organised by a committee, under the chairmanship of Mr. E. G. Phillips, M.I.Mech.E., M.I.E.E., representative of local industries and institutions in collaboration with the Regional Council for Further Education, the University of Nottingham and the East Midlands Kindred Engineering Societies. The syllabus covers a selected range of subjects of particular interest and importance to the works and plant engineer, and is designed not only to increase knowledge but to make better use of existing knowledge and to promote the application of modern techniques in works engineering practice over a wide field. The principal subjects will be as follows: fundamentals of heat and power, the internal combustion engine, the gas turbine, back pressure and pass out turbines, the steam engine, fundamentals of heat transfer, grates and stokers, boilers, economisers and superheaters, distribution and economic use of process steam, and instrumentation. The fee for the full nineteen weeks' course will be £4 4s. The honorary secretary to the course, from whom all information can be obtained, is Dr. H. K. Lloyd, Department of Civil and Mechanical Engineering, University of Nottingham, University Park, Nottingham.

LOSSES THROUGH U.S. STEEL STRIKE.—Mr. Benjamin Fairless, president of the United States Steel Corporation, has recently commented on the effects of the strike in the American steel industry, which ended on July 26th, having lasted fifty-four days. The Corporation's production losses, Mr. Fairless has stated, have been estimated at 7,000,000 ingot tons of steel, much of which was vitally needed for defence purposes. One of the most serious problems raised in connection with the steel strike, Mr. Fairless added, was the companion strike in the iron ore mines in the Lake Superior region. Based on estimates of next winter's needs, iron ore lake shipments to the Corporation's steel mills were 2,000,000 tons less than they should be at this season, and would need to be supplemented by rail deliveries.

BRITISH PLASTICS EXHIBITION AND CONVENTION.—The second British Plastics Exhibition and Convention will be held at Olympia, London, from June 3 to 13, 1953, opening on the day following the Coronation. It is stated that the exhibition will occupy the whole of the National Hall, Olympia, and already over 82 per cent of the space has been applied for by seventy-eight firms, including twenty-eight suppliers of raw materials, twenty-four fabricators and moulders, and nineteen plant manufacturers. The convention will be on the same basis as in 1951 with discussions of papers, presented by leading authorities, on the most recent developments and rapidly developing materials in the industry. Special sessions will reveal new uses of plastics in industry, while the growing importance of unplasticised PVC (poly-vinyl-chloride) and glass-reinforced plastics will be dealt with in detail. Other sessions will cover subjects of interest to engineers, moulders and salesmen. The convention will open with an inaugural address on the afternoon of Wednesday, June 3rd, and continue throughout the period of the exhibition in the same hall. The exhibition is being organised by *British Plastics*, Dorset House, Stamford Street, London, S.E.1, with the full co-operation of the British Plastics Federation.

Personal and Business

PELAPONE ENGINES, Ltd., has appointed W. Crockatt and Sons, Ltd., Darnley Street, Glasgow, S.1, its sole representative in Scotland.

THE EARL OF DERBY has been nominated as president of the Royal Agricultural Society of England for 1953. Mr. Carol Fellowes has been appointed assistant secretary to the Society.

B. AND P. SWIFT, Ltd., of Airport Works, Rochester, Kent, announces that Mr. E. Biltcliffe, A.M.I.Mech.E., is to take charge of the technical sales of its "Motogears" and worm reduction units.

THE NATIONAL COAL BOARD states that Mr. T. S. Charlton has been appointed to succeed Alderman G. H. Jones as deputy chairman of the West Midlands Divisional Coal Board. Alderman Jones has accepted an invitation to remain on the Board as a part-time member

THE MINISTER OF SUPPLY has appointed Rear-Admiral M. S. Slattery to be chairman of Short Brothers and Harland, Ltd., Belfast, in succession to Sir Edward Herbert, who has resigned owing to other business commitments. Admiral Slattery has been managing director of the company for the past four and a half years.

Contracts

DURING the past month the British Electricity Authority has placed contracts for equipment for power stations, transforming stations and transmission lines amounting in the aggregate to £6,665,970. The principal contracts include:—Woolwich power station, boiler-house structural steelwork (Redpath Brown and Co., Ltd.); Brighton "B" power station, two 320,000 lb per hour boilers (Babcock and Wilcox, Ltd.); Littlebrook "C" power station, Dartford, Kent, coal-handling plant (Fraser and Chalmers Engineering Works); Croydon "B" power station, raw water main and pump-house (Concrete Piling, Ltd.); Connah's Quay power station, near Flint, two 300,000 lb per hour boilers (International Combustion, Ltd.), foundations to coal-handling plant and ancillary works (Yorkshire Hennebique Contracting Company, Ltd.), and 132kV, 2500MVA switchgear (Ferguson, Pailin, Ltd.); Doncaster power station, auxiliary power, control and alarm cables and connections (Enfield Cables, Ltd.); Stella North power station, near Newcastle upon Tyne, steel frame for turbine house, boiler-house, workshops and stores buildings (Cleveland Bridge and Engineering Company, Ltd.) and six boiler feed pumps (G. and J. Weir, Ltd.); Stella South power station, steel frame for turbine-house, boiler-house, workshops and stores buildings (Cleveland Bridge and Engineering Company, Ltd.) and boiler feed pumps (Sulzer Bros. (London), Ltd.); and Staythorpe (Newark) to Drakelow (Burton-on-Trent), 275kV twin 0·4 square inch transmission line (W. T. Henley's Telegraph Works Company, Ltd.).

British Patent Specifications

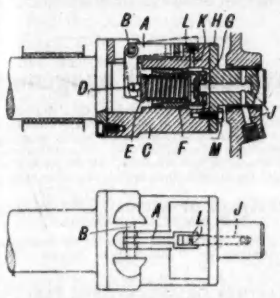
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

GAS TURBINES

676,948. February 26, 1951.—REGULATING DEVICE FOR GOVERNING THE VELOCITY OF A SHAFT, Maschinenfabrik Oerlikon, Oerlikon, near Zurich, Switzerland.

As indicated in the drawing, a bell-crank lever *A* with arms at right angles to each other, turns about a crank pin *B*, eccentrc to the axis of rotation of the body *C*. The upper arm, representing the weight, is in the form of a fork and is held in equilibrium by the lower arm, the end of which rests on a pin *D* on a



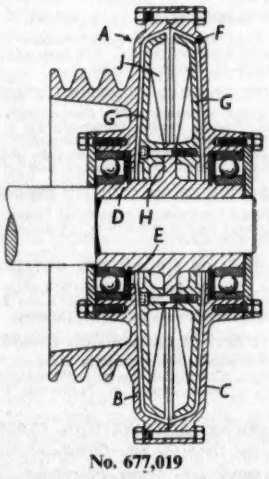
No. 676,948

member *E*, by means of which a spring in a hollow screw *F* in the axis of rotation is compressed. The screw is screwed into the body by means of two wings *G*, which engage with corresponding grooves arranged in the cover *H* fastened to the body by the screws. The pressure of the regulating system is transmitted from the bearing through the holes *J* in the cylindrical part of the cover, then through a channel *K* and two regulating apertures *L*. The upper arm of the lever acts directly on the pressure of the regulating system by uncovering the two apertures *L* under the action of the centrifugal force. The tension of the spring is regulated by rotation of the cover, thus altering the set distance between the points of support of the spring. The number of angular positions of the cover are equal to the number of locking bolts *M* around its circumference. The regulating device can be used for a gas turbine plant, where this regulator comes into action at the point when the normal velocity of rotation of the turbine wheel of the compressor is exceeded.—*August* 6, 1952.

POWER TRANSMISSION

677,019. September 30, 1949.—TRANSMISSION COUPLINGS, Eric Crisp Lewis, 10, Kenilworth Court, Putney, London, S.W.15.

The coupling is designed with a view to obtaining maximum slip at low speeds, whilst at higher or working speeds a very minimum of slip or practically a solid drive. Referring to the drawing, the driving member *A* is formed from two halves *B* and *C* secured together and the outer half of the casing being formed integral with a V-belt pulley. The casing is free to



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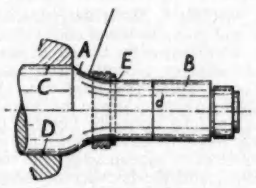
rotate about the driven shaft on ball bearings on a hub member *D* fast with the shaft, sealing washers *E* being provided to seal the ball bearings from the interior of the casing. The interior of the casing closely follows the outer contour of the rotor *F*, which is built up of two dished circular members *G* secured to the hub member by means of the annular web *H*, the dished members forming an annular reservoir *J* within the rotor. The casing and also the interior reservoir of the rotor are partially filled with powdered or granulated metallic or non-metallic material, the reservoir *J* thus serving to accommodate some of the powder. The action of the coupling is as follows :—Upon the outer casing being rotated slowly substantially no drive is imparted to the rotor, but on increased speed owing to the friction created by the powder the rotor commences to rotate or to rotate at a speed nearer to that of the casing. As the rotor gathers speed owing to centrifugal force, some powder is expelled from the reservoir *J* to be impacted between the outer mutually inclined peripheral surfaces of the rotor and the adjacent wall of the casing by centrifugal force. When this state is reached a substantially solid drive is effected between the casing and rotor with a minimum of slip. Upon the speed of the casing being reduced from working speed to idling speed, some powder returns to the reservoir of the rotor so that a condition of impacted powder between the rotor and the casing breaks down, and also owing to the reduced effective weight of powder in the coupling a maximum degree of slip is obtained in the drive transmitted. With a coupling constructed in accordance with the drawing the rotor *F* is 9in in diameter and the coupling contains between 1 lb 4 oz to 1 lb 8 oz of powder, loads up to 11 h.p. can be transmitted at working speeds ranging between 1500 to 3000 r.p.m. The powder employed is preferably metallic, e.g. iron of a mesh of 100, and it has been found beneficial to include in the weight of powder from 5 to 10 per cent of graphite to act as a lubricant.—*August* 6, 1952.

RAILWAY ENGINEERING

676,982. October 14, 1949.—AXLES FOR RAILWAY CARS, Degerfors Jarnverks Aktiebolag, Degerfors, Sweden.

As shown in the upper drawing, the axle portion *A* extends smoothly from the journal *B* to the wheel seat *C* or *D* without sudden change of the diameter, the diameter increasing continuously from the point *E* to the wheel seat *C*. A portion of the hub of the wheel disc is also shown, the hub being pressed on



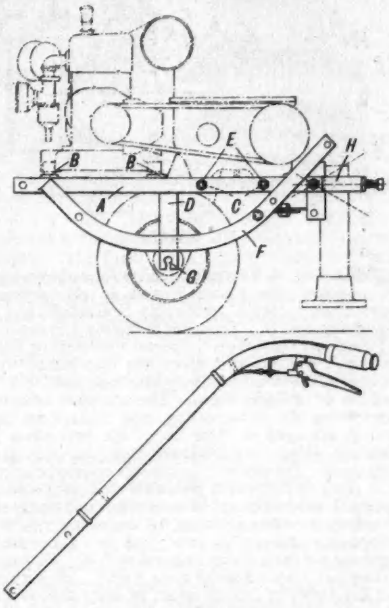
No. 676,982

the wheel seat of the axle. The change of diameter between the journal and the wheel seat is such that the radius of curvature of the portion which joins the cylindrical journal is greater than 0·3 *d*, *d* being the diameter of the journal. No inconvenience will arise even if the radius of curvature is made smaller than that shown in the drawing, 0·4 *d*, 0·5 *d* or still larger, as the fatigue strength increases as the radius of curvature increases. The risk of axle fracture arises, however, only when the radius of curvature is smaller than the above-indicated limit. Designs for a tubular shaft are also given.—*August* 6, 1952.

AGRICULTURAL ENGINEERING

676,818. February 2, 1950.—SINGLE-WHEELED AGRICULTURAL TRACTOR FRAMES, Thomas Arthur Hill, 20, Gladstone Terrace, Grantham, Lincolnshire ; and Barford (Agricultural), Ltd., of Grantham.

The object of the invention is to provide a light and sturdy tractor to which implements can be quickly fitted at either end ; has a nice balance for steering wheelbarrow fashion from the rear end ; and suits walking operators of different heights, while the handlebars are detachable for packing purposes. As the drawing shows, the chassis frame comprises a pair of spaced main longitudinal members *A*, joined together by two transverse flat bars *B* and by two transverse round bars *C* fixed by nuts *E*. The rectangular frame thus formed is carried by two vertical legs *D* and two curved bars *F*, which form axle brackets, one on each side of the frame. Each of the legs is welded to one of the members *A* approximately midway between the ends. Each curved bar *F* of flat strip metal is welded to one of the legs and extends forwards and rearwards. The legs terminate in slots *G* designed for fixing the axle of the wheel of the tractor. As indicated in the drawings, the transverse bars *B* serve as bearers for an engine carried at the front end of the chassis frame above the frame, and they are used to support a gearbox carried behind the engine. The gearbox receives power from the engine through a belt drive controlled by a clutch. The drive from the gearbox to the wheel is by means of a chain. A tractor having such a frame is designed to be guided like a wheelbarrow by means of a handle unit attached to one end of the chassis frame. The handle unit, shown in the lower drawing, comprises a pair of arms, which are tied together by cross bracing bars. The arms are provided with hand grips and Bowden control levers at their upper ends. The lower ends are designed to be bolted to the curved bars *F*. The handle unit is thus readily detachable for packing



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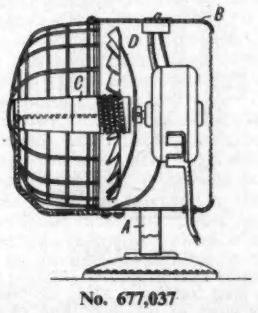
and transport. At the end of the chassis frame on which the gearbox is mounted an implement-carrying framework *H* is fitted. Holes are also provided at the end of the chassis frame on which the engine is mounted, so that the implement framework can be fitted at the forward end.—*August* 6, 1952.

ELECTRICAL ENGINEERING

677,037. July 12, 1950.—ELECTRIC RADIANT FAN HEATERS, The British Thomson-Houston Company, Ltd., Crown House, Aldwych, London, W.C.2.

The invention relates to an electric heater providing both radiated heat and forced movement of heated air. Referring to the drawing, the electric heater is mounted on a trunnion *A* adjustably affixed to a base and to a shell *B* enclosing the heating element and other operating parts. The shell has a front guard. The other end of the shell is covered by a rear guard or screen. The heating element is a ceramic cylindrical core *C* having a coiled resistance wire wrapped around its surface. It is designed so that when it is operated on normal voltage it is at a



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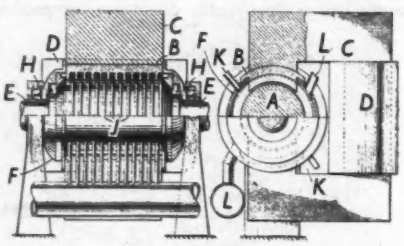
cherry-red heat. To support it a cylindrical socket member is affixed centrally to the front guard. The heat is projected from the shell by a combined reflector and fan which is fabricated from a circular piece of sheet metal. Aluminium or copper, coated with a clear lacquer, is particularly suitable, since neither of these metals is affected by rust and both may be highly polished for a reflecting surface. The drawing shows the general arrangement of the fan and its driving motor. The dual function of the fan reflector increases the efficiency of the heating apparatus, permitting smaller overall size for accomplishing the same heating effect.—*August* 6, 1952.

MEASURING INSTRUMENTS AND DEVICES

676,624. December 15, 1948.—ABSORPTION DYNAMOMETERS, Power Jets (Research and Development), Ltd., 25, Green Street, London, W.1. (*Inventor : Peter Martin.*)

The invention relates to absorption dynamometers for measuring a rotational torque transmitted from a rotor driven by a power unit to a floating stator

co-operating with the rotor by the creation of magnetic fields between them. The drawings illustrate diagrammatically, in partly sectioned side and end elevations, an absorption dynamometer intended for high-speed operation at speeds from 20,000 to



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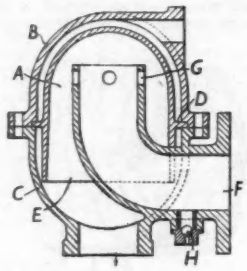
70,000 r.p.m. A magnetic circuit is formed by a rotor *A*, opposed pole pieces *B*, and an electromagnet comprising a core *C* (preferably laminated), and an energising coil *D*. The rotor is mounted in bearings *E*, which are themselves supported by a floating stator casing *F*, which also supports the pole pieces. The casing is made of non-magnetic material, such as bronze or stainless steel. The complete assembly comprising the stator casing, pole piece, core, and coil is arranged to float about the rotor axis on bearings *H* so that torsional loads on it may be measured. The assembly is suitably counterbalanced. The rotor is made of high-tensile steel with suitable magnetic properties at the operating conditions, and is provided with evenly spaced peripheral ribs *J* to afford adequate cooling area ; the pole pieces are of appropriate shape to correspond with it. The stator casing has inlet and outlet ports *K* and *L*, respectively, for the supply of cooling water, which is directed into the smaller diameter of the rotor between the ribs ; the water is arranged to flow circumferentially in a direction opposite to the direction of rotation of the rotor.—*July* 30, 1952.

INTERNAL COMBUSTION ENGINES

677,334. May 20, 1949.—Silencing and Cooling Device for Exhaust Gases, Alfred George Langdon, 77, Derby Road, Southampton, Hampshire.

The invention relates to a silencing and cooling device for the exhaust gases of internal combustion engines, particularly those used in water craft. In the drawing is shown a chamber *A* of inverted " U " vertical cross-section. It is secured in an outer casing consisting of a two-part casting *B* and *C*, the upper part *B* being of inverted " U " vertical cross-section similar to the chamber *A*, whilst the lower part *C* is of similar general shape. The inner chamber is held in place by a circumferential flange *D*, which is secured in a recess formed in the part *B* of the outer casing at the joint. The chamber wall extends well



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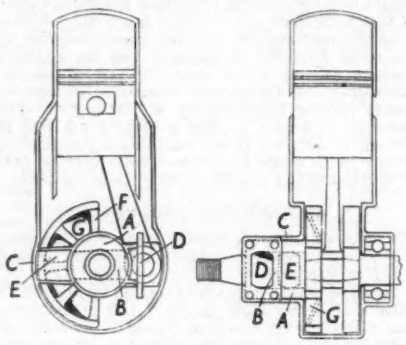
below the joint forming a skirt, its lower edge *E* terminating close to the inner wall of the lower part of the casing *C*. The lower part of the casing has an integral inlet *F* for the exhaust gases, which extends from the lower part horizontally outwards from the casing, and turns through a right angle into the chamber *A*, so that its upper end is a short distance from the crown of the dome of the chamber. The outer end of the pipe is flanged for fixing to an exhaust manifold. The upper part *B* of the casing is formed with a flanged duct for connection to a water supply. The bottom of the lower half of the casing *C* has a large outlet orifice for connection to an exhaust pipe. When the silencer is fitted in operative position on the exhaust manifold of an engine, the exhaust gases pass into the inlet *F* and thence through the pipe end and apertures *G* to be discharged against the dome of the chamber *A*, which is cooled by water flowing through the duct and around the jacket to the lower part of the casing *C*, where it mixes with the gases which have passed downwards from the chamber. The cooled mixture then passes from the casing through the outlet in direction of arrow to the exhaust pipe, which is thus kept in a cool condition. The valve *H* is provided to prevent a vacuum being set up when the engine is cooling, so that the possibility of water and vapour being sucked back into the engine is obviated.—*August* 13, 1952.

677,067. February 21, 1949.—Two-Stroke Internal Combustion Engine, Lewis George Cullwick, 32, Marine Parade, Eastbourne, Sussex.

As illustrated in the drawing, the main journal of a crankshaft *A* is large in diameter and length to enable it to have a large porthole *B* running transversely through it at an angle of 60 deg. This journal runs in a plain bearing housed in a crankcase *C*, also having portholes, one rear being the intake *D* and one front *E* which discharges into the inside of the crankcase. At one position of the suction stroke of the engine's cycle the portholes *B*, *D* and *E* are fully in line at an angle of 60 deg., forming a rotary valve as shown in the accompanying drawings. In one with the journal *A* is the balance weight *F*. This is shaped to act as an impeller or inducer fan to influence petrol mixture or air from the rotary valve into the crankcase. The impeller or inducer fan *G* in its travel will come in



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line with the porthole *E*. When the piston is at bottom dead centre and going to travel on its up or suction stroke, the rotary valve *B*, *D* and *E* just begin to open, the impeller or inducer fan *G* just entering porthole *E* area inside the crankcase. When the piston is halfway on its up stroke the portholes in the rotary valve are fully open, the impeller or inducer fan is halfway round its travel. When the piston is at top dead centre of its suction stroke the rotary valve has just closed, and the impeller or inducer fan *G* has just left the porthole area *E*.—*August* 6, 1952.

Codes of Practice

MASTIC ASPHALT ROOFING

The Council for Codes of Practice for Buildings has now issued in final form Code 144.201, " Mastic Asphalt Roofing." The code gives specifications for mastic asphalt and for the various accessory materials generally used in conjunction with it. It includes recommendations on the preparation of various types of sub-structure, on the thickness and number of coats required for varying conditions and on methods of protection from solar heat. Advice is given on the preparation for, and technique of, laying the mastic asphalt. The code includes a large number of diagrams illustrating methods of laying mastic asphalt roofing and arrangements for certain closely associated damp-proof courses. Copies may be obtained from the British Standards Institution, 24/28, Victoria Street, London, S.W.1, price 5s. 6d., post free, Reference CP 144.201 (1952).

Catalogues

Sturtevant Engineering Company, Ltd., Southern House, Cannon Street, London, E.C.4.—Pamphlet illustrating axial flow fans.

Wellman Bibby Company, Ltd., Parnell House, Wilton Road, London, S.W.1.—Catalogue dealing with the Bibby resilient coupling.

Incandescent Heat Company, Ltd., Smethwick, Birmingham, 40.—Booklet giving details of a service in industrial heat engineering.

Houchin, Ltd., 447, Grand Buildings, London, W.C.2.—Pamphlet describing the 93kW-116kVA, 1500 r.p.m. diesel generating set.

Croda, Ltd., Croda House, Snaith, Goole, Yorks.—Booklet " Metacon 516," describing a concentrated rust remover and short-term anti-corrosive treatment.

Intermit, Ltd., 37, Bradford Street, Birmingham, 5.—Brochure illustrating filters, screens, ventilator gauzes and fabricated gauze components for various purposes.

Bailey Meters and Controls, Ltd., Moorgate Hall, Moorgate, London, E.C.2.—Leaflet C.8, describing the three-element steam temperature control system.

Elcontrol, Ltd., 10, Wyndham Place, London, W.1.—Data Sheets Nos. 6 and 7, describing electronic weld timers and furnace safety systems, respectively.

Crane, Ltd., 45/51, Leman Street, London, E.1.—Booklet No. 380, covering a range of gun metal and cast iron valves, Globe and Gate patterns, for a variety of services.

Wright Electric Motors (Halifax), Ltd., Century Works, Pellon Lane, Halifax.—Jubilee Catalogue No. 500, covering electric motors a.c. 1 to 150 h.p., d.c. 1 to 50 h.p.

Standard Telephones and Cables, Ltd., Connaught House, Aldwych, London, W.C.2.—Bulletin F/srt. 1, Edition 5, dealing with codes, dimensions and weights of rectifier stacks.

Electromagnets, Ltd., Boxmag Works, Bond Street, Birmingham, 19.—Catalogue Leaflet No. 62m, giving technical details and photographs of magnetic conveyor head unit.

Sunvic Controls, Ltd., 10, Essex Street, Strand, London, W.C.2.—Folder illustrating the complete range of Moore " Nullmatic " instruments for the automatic control of industrial processes.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SPECIAL LIBRARIES AND INFORMATION BUREAUX

Fri. to Mon., Sept. 19th to 22nd.—The Hayes, Swanwick, Derbyshire, Conference on " Information Service : Theory and Practice."

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, Sept. 5th.—Crewe Branch : Crewe Arms Hotel, Crewe, " Ethical Implications of Science," J. Levitt, 7.30 p.m.—Liverpool Branch : Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool, 2, Chairman's Address, I. Harper, 7.30 p.m.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

To-day to Wed., Sept. 10th.—Annual Meeting in Belfast.

ENGINEERS' GUILD

Thurs., Sept. 25th.—Caxton Hall, Caxton Street, Westminster, London, S.W.1, Annual General Meeting, 6 p.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., Sept. 8th.—Sheffield Centre : Medical Library, The University, Western Bank, Sheffield, Chairman's Address, H. Dick, 6.30 p.m.

INCORPORATED PLANT ENGINEERS

Thurs., Sept. 11th.—Newcastle upon Tyne Branch : Roadway House, Newcastle upon Tyne, " Liquid Fuel Firing," Alan Moore, 7.30 p.m.

Sat., Sept. 13th.—Dundee Branch : Works visit to Expanded Rubber Company, 2.15 p.m.

Mon., Sept. 15th.—Liverpool and N. Wales Branch : Radiant House, Bold Street, Liverpool. " Amenities in Industry," H. S. Crump, 7.15 p.m.

Tues., Sept. 16th.—St. Alban's Branch : Peahen Hotel, St. Albans, " Radio and Television Interference," C. E. Hollingworth, 7.30 p.m.—Glasgow Branch : Engineering Centre, 351, Sauchiehall Street, Glasgow, " Mechanical Handling Equipment and Methods," F. T. Dean, 7 p.m.

INDUSTRIAL WELFARE SOCIETY

To-day to Sat., Sept. 13th.—Keble College, Oxford, Third Annual Conference for Apprentices, Theme : " The Approach to Industrial Responsibility."

INSTITUTE OF FUEL

Tues. and Wed., Oct. 28th and 29th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, Conference, " A Special Study of Ash and Clinker in Industry."

INSTITUTE OF PETROLEUM

Wed., Sept. 10th.—26, Portland Place, London, W.1, " Mud Control in the Fields of the Iraq Petroleum and Associated Companies," A. W. Paxton, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Tues., Sept. 9th.—Midlands Centre : Crown Inn, Broad Street, Birmingham, " Some Factors Influencing the Choice of a Crankcase Lubricating Oil," A. Towle, 7.30 p.m.

Wed., Oct. 1st.—Royal Society of Arts, John Adam Street, London, W.C.2, Annual General Meeting, 6.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Sept. 24th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, Presidential Address, C. M. Cock, 5.30 p.m.

INSTITUTION OF MINING AND METALLURGY

Tues. to Thurs., Sept. 23rd to 25th.—Imperial College of Science and Technology, Prince Consort Road, South Kensington, London, S.W.7, Symposium on Mineral Dressing.

INSTITUTION OF PRODUCTION ENGINEERS

Tues., Sept. 9th.—Coventry Graduate Section : Hare and Squirrel Hotel, Cow Lane, Coventry, " Production Panel," Discussions on most aspects of Production Engineering, 7.30 p.m.

INTERNATIONAL MACHINE TOOL EXHIBITION

Wed. to Sat., Sept. 17th to Oct. 4th.—Olympia, London.

IRON AND STEEL INSTITUTE

Tues. to Thurs., Oct. 7th to 9th.—Special meeting in Swansea.

OLD CENTRALIANS

Mon., Sept. 15th.—Chez Auguste Restaurant, 47, Frith Street, London, W.1, " The Muniments of Westminster Abbey," R. P. Howgrave-Graham, 12.55 p.m.